SUSTAINABILITY MANAGEMENT OF THE RECOMMENDED QUALITY AND QUANTITY OF DRINKING WATER IN MALAWI: DEVELOPING A FRAMEWORK

A thesis

by

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ABSTRACT

Supply of safe drinking water is well-recognised as a catalyst for improving public health and social welfare as well as spurring economic growth. For this to be achieved, the water used should be both adequate and safe for human consumption. However, it has been noted that in Malawi the quality and quantity of water used by the consumers deteriorates and decreases respectively as time passes after commissioning of the water supply systems.

For the quality and quantity of drinking water (drinking water supply services) to be sustainable, there is a need to manage all the factors that affect them. However, not all the factors are currently managed. With only some of the factors being managed, not all the aspects required for sustainability of the quality and quantity of drinking water are maintained. It is also noted that the factors that are managed are selected based on their popularity and perceived order of importance. As such, the factors that are managed are not necessarily the root causes of the deterioration of the quality and quantity of the supplied drinking water. While this is the case, it is known that for a problem to be solved completely, there is a need to deal with its root causes. In addition, addressing of the root causes, which are fewer than the total number of the factors that affect sustainability of drinking water supply (DWS) services, is a simple way of managing all the factors. Therefore, the aim of this research was to identify the root causes of sustainability failure of DWS services in Malawi, evaluate the outcomes of managing the root causes on sustainability of DWS services, and develop a framework for managing the identified root causes to improve sustainability of DWS services.

Root cause analysis, survey and multiple case studies were employed as the research strategies for this study. Five DWS experts took part in the root cause analysis, ten water supply systems were studied as cases while 40 respondents participated in the survey. All the participants and the case water supply systems were from Malawi. Both qualitative and quantitative data were collected and analysed in the study.

The findings of this research include the identification of 7 combined effects through which various factors affect sustainability of DWS services in Malawi. The research has also established that interaction of the factors that affect sustainability of DWS services in Malawi is kick-started by 26 root causes. Comprehensive sets of strategies and tactics have been developed to address the 7 combined effects and the 26 root causes respectively. Six critical requirements necessary for effective implementation of the strategies and tactics have also been identified. Accordingly, an overarching framework, with step-by-step instructions on how to improve sustainability of DWS services in Malawi, has been developed. The theoretical contribution of this research is that there will be increased understanding of the issues that affect sustainability of DWS services in Malawi and other countries with similar contexts. As regards practical contribution, the framework developed in this research - when used by the DWS practitioners, managers and policy makers - is expected to lead to improved sustainability of DWS services in Malawi and other countries with similar contexts.

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GLOSSARY OF KEY TERMS

Combined effect is a factor that directly affects sustainability of drinking water supply services after being triggered by other factors.

Drinking water is water which is available to people for consumption.

Drinking water supply coverage is a percentage of the population that has access to improved water sources.

Drinking water supply service is a flow of water of a particular quality and quantity.

Drinking water supply service sustainability is continued flow of water at the same rate and quality as per the design of the supply system.

Factor is something that contributes to or has an influence on the combined effect that affects sustainability of drinking water supply services.

Framework is a logical structure for presenting complex information in an organised manner.

Functional water point is a water point that yields water regularly and is used on a daily basis.

Improved water sources are the sources of water which are protected from contamination but are not necessarily free from pathogens.

Maintenance of infrastructure within a short time is when the broken down infrastructure is maintained before the consequent disruption of drinking water supply forces people to fetch water from other sources.

Prolonged breakdown of infrastructure is when the broken down infrastructure takes long to maintain such that the consequent disruption of drinking water supply forces people to fetch water from other sources.

Residual chlorine is the amount of chlorine available in the treated water to inactivate disease-causing organisms.

Root cause is a factor which when fixed, the problem goes away and does not come back.

Safe drinking water (also known as potable water) is water of high quality that can be consumed or used with low risk of immediate or long-term harm to life.

Safe drinking water supply is the provision of safe water by a designated entity to a particular area.

Service sustainability factor is an influence which affects sustainability of a service.

Strategy is a high level plan to achieve a specific objective.

Sustainability failure of drinking water supply services is the failure of drinking water supply services to be sustainable.

Tactic is an action that is used to achieve a particular strategy.

Water available for supply is the total quantity of water produced and sent into a water supply system by a service provider.

Water available to the user is the water which the user is able to collect from the supply point (transports and/or stores it, where applicable) ready for use.

Water supply system is an arrangement of engineered hydrologic and hydraulic components which provide water supply.

ABBREVIATIONS AND ACRONYMS

AF	-	Additional factor
AfDB	-	African Development Bank
ANOVA	-	Analysis of Variance
CE	-	Combined effect
CF	-	Conceptual factor
Cq	-	Consequence
CR	-	Critical requirement
DWS	-	Drinking Water Supply
ESCOM	-	Electricity Supply Commission of Malawi
FS	-	Favourable state
GDP	-	Gross Domestic Products
HDPE	-	High-density polyethylene
ILO	-	International Labour Organisation
IOB	-	Policy and Operations Evaluation Department of the Netherlands Ministry of Foreign Affairs
IPCC	-	Intergovernmental Panel on Climate Change
IRC	-	International Water and Sanitation Centre
KMO	-	Kaiser-Meyer-Olkin
MCCCI	-	Malawi Confederation of Chambers of Commerce and Industry
MDG	-	Millennium Development Goal
M&E	-	Monitoring and Evaluation
MK	-	Malawi Kwacha
NGO	-	Non-Governmental Organisation
NRWB	-	Northern Region Water Board
NWDP	-	National Water Development Programme
O&M	-	Operation and Maintenance
PACN	-	Pan Africa Chemistry Network
Q	-	Research question
RC	-	Root cause
RGWSS	-	Rural Gravity-fed Water Supply System
RWSN	-	Rural Water Supply Network
S	-	Strategy
SPSS	-	Statistical Package for the Social Sciences
T	-	Tactic
UN	-	United Nations
UNCHS	-	United Nations Commission for Human Settlement
UNDP	-	United Nations Development Programme
UNGA	-	United Nations General Assembly
UNICEF	-	United Nations Children’s Fund
USA	-	United States of America
US$	-	United States Dollar
WELL	-	Water and Environmental health at London and Loughborough
WHO	-	World Health Organisation
WSP	-	Water and Sanitation Programme
WSS	-	Water Supply System
WSSCC	-	Water Supply and Sanitation Collaborative Council

CHAPTER ONE - INTRODUCTION

1. INTRODUCTION

Safe drinking water (also known as potable water) is water of high quality that can be consumed or used with low risk of immediate or long-term harm to life (Greenhalgh, 2001). Provision of safe drinking water to a particular area by a designated entity is known as water supply. As such, safe drinking water supply (DWS), which is a combination of the terms 'safe drinking water' and 'water supply', is the provision of safe water to a particular area by a designated entity.

The two main indicators of whether or not the DWS will maintain and/or improve public health, which is the main purpose of DWS, are the quality and quantity of the water used (Bostoen, 2005; UNICEF and WHO, 2012). In Malawi, drinking water is said to be safe for human consumption when at least the number of faecal coliforms per 100 millilitres of water is not more than 10 in 99% of the samples (Malawi Standards Board, 2005). As regards quantity, in Malawi drinking water is said to be adequate when it is not less than 36 litres per capita per day (Malawi Ministry of Irrigation and Water Development, 1994). However, the quality and quantity of drinking water in Malawi deteriorate as time passes after commissioning of the water supply systems. For example, at the time of preparing this thesis, the quantity of water supplied to most users was less than the recommended minimum. This was the case because either the water flows at the taps were very low or the water supply was intermittent. These situations forced some people to collect and use unsafe water to complement the available inadequate safe water. In most cases, such people ended up suffering from water-borne diseases despite having access to some safe water (Malawi Ministry of Health, 2007-2011). Further, inadequate quantity of supplied drinking water forced water-using industries and commercial enterprises, which were not able to store enough water or source it from elsewhere, to operate for less than the planned period per day. The consequence was that such enterprises did not realise the anticipated benefits from their businesses (MCCCI, 2013). There is, therefore, a need to find ways of addressing the situation so that all users should have access to adequate safe water all the time. Once found, the Government of Malawi could use such ways to realise its vision of providing safe and adequate drinking water to all its people all the time, dubbed 'Water for all, always' (Malawi Ministry of Irrigation and Water Development, 2005).

It is argued in this thesis that for DWS services to be sustainable in Malawi and other countries with similar contexts, it is essential that all the root causes of sustainability failure of DWS services in a water supply system should be addressed. This is important because management of all the root causes ensures complete resolution of problems.

1.1 IMPORTANCE OF SAFE DRINKING WATER SUPPLY (DWS)

Supply of safe drinking water is important for a number of reasons; it improves public health, reduces mortality and spurs economic development (Braune and Xu, 2010; Montgomery et al, 2009). Health of the people who consume and/or use potable water improves because they do not suffer from water-borne and water-washed diseases. The welfare of such people also improves. On the contrary, health and welfare of the people who suffer from water-borne and water-washed diseases are negatively affected, and this has negative impact on national economies. World Bank (2008) estimates that the total effects of diarrhoeal diseases and the associated malnutrition (including the long-term effects on education and income for the affected people) cost low-income governments like Malawi up to 9% of their annual gross domestic product (GDP). This loss is prevented where adequate safe water is supplied to people. The other benefits related to health are that money is not spent on medical bills, no time is lost in hospitals receiving treatment, and people do not die of water-borne and water-washed diseases.

Apart from health benefits, potable water supply promotes economic growth (Schwartz and Johnson, 1992; Whittington and Swarna, 1994). This is the case in that availability of potable water encourages establishment of commercial and industrial enterprises which require potable water. Some of such enterprises add value to locally available products such as crops and minerals. The presence of such enterprises enables governments to earn more income through collection of taxes and sale of products with additional value. In addition, implementation of DWS projects spurs economic growth through increased efficiency in production and supply of potable water, increased production of goods and services, and increased job creation and employment (Schwartz and Johnson, 1992).

Further, the other benefit is that where safe drinking water is available in the homes and/or nearby places, time is saved (Carter et al, 1999). It is estimated that families spend an average of three hours per day fetching water for a family of six in rural Africa (PACN, 2010). This much time is saved where drinking water is supplied in homes or nearby places. The saved time is then used for socioeconomic activities (Whittington and

Swarna, 1994). It is estimated that health and time-saving benefits of DWS are as much as 11 times the associated costs (Banerjee et al, 2008).

Adequate water supply also results in high school enrolment, and high retention rates of girls in schools as the girls do not spend much time fetching water (PACN, 2010; UNICEF, 2006; WHO/UNICEF, 2000).

In summing up the importance of water to life, Szent-Gyorgyi (1893-1986) states that:

"Water is life's matter and matrix, mother and medium. There is no life without water"

1.2 THE STATE OF GLOBAL DRINKING WATER SUPPLY

Despite being so important, safe drinking water is not available to all the people globally. In 1990, 24% of the people in the world had no access to improved water sources (UNICEF/WHO, 2012). This prompted the United Nations to include provision of safe drinking water to people as one of the targets under the Millennium Development Declaration (Hulme, 2009; UNGA, 2000). The target was to reduce the proportion of people without sustainable access to safe drinking water by half by the year 2015. This meant that 89% of the people worldwide were expected to have access to improved water sources by 2015.

Progress made so far on this target is excellent. By 2010, the target had been achieved, 5 years ahead of the target date of 2015 (UNICEF/WHO, 2012). As such, it is projected that by 2015, 91% of the people in the world, which is more than the targeted 89%, will have access to improved water sources (WHO/UNICEF, 2010). Table 1 shows the timeline of how the target was achieved from 1990 to 2010.

Table 1: Access to improved water sources worldwide

Year	1990	2000	2010
Coverage (%)	76	83	89

Source: UNICEF/WHO, 2012

While the figures in table 1 look impressive, the situation is different in some specific countries and regions. For example, Sub-Saharan Africa is struggling to achieve its target of supplying 75% of its people with safe water by 2015. By interpolation, the target for year 2010 was 70%. However, only 61% of the people in the Sub-Saharan Africa had access to improved water sources by 2010 (UNICEF/WHO, 2012). The percentages of the people in the Sub-Saharan Africa who had access to improved water sources between 1990 and 2010 are as shown in table 2.

Table 2: Access to improved water sources in Sub-Saharan Africa

Year	1990	2000	2010
Coverage (%)	49	55	61

Source: UNICEF/WHO, 2012

If the trend shown in table 2 continues, only 64% of the people in the Sub-Saharan Africa will have access to improved water sources by 2015, thereby missing the target of 75%. This shows that progress in increasing the proportion of people who have access to improved water sources (DWS coverage) in the Sub-Saharan Africa has been slower than expected. In fact, UNDP (2006) notes that the rate at which DWS coverage has been increasing in the Sub-Saharan Africa is the slowest of all the regions in the world.

The main reason for the low DWS coverage in the Sub-Saharan Africa has been identified as low sustainability level of DWS services i.e. failure to maintain the quality and quantity of drinking water (WHO/UNICEF, 2004). Estimates by RWSN (2010) indicate that only 67% of the water points are functional in the region at any given time. This is the case due to high breakdown rates of the water supply systems as a result of poor quality water supply systems, inappropriate management structures and lack of affordability by the communities, among other reasons (Harvey, 2011; WHO/UNICEF, 2004).

1.3 DRINKING WATER SUPPLY SITUATION IN MALAWI

DWS situation in Malawi is discussed below under the following three (3) topics, namely; sources of drinking water, institutional set-up for DWS, and DWS targets and achievements.

1.3.1 Sources of drinking water in Malawi

People in Malawi use water from piped water supply systems, hand-pump boreholes, wells, rivers, streams, ponds, lakes, dams and springs (Malawi National Statistical Office, 2009). Piped water supplies, hand-pump boreholes and protected wells are improved water sources while the rest of the above sources are not (Stoupy and Sugden, 2003).

The distribution of the people in Malawi in 2008 (when the latest comprehensive study was conducted) per the type of water source was as shown in table 3.

Table 3: Distribution of people in Malawi in 2008 per the type of water source

Water source	**Number of people**	**Percentage of people**
Piped - house connections	379,238	2.9
Piped - standpoints	2,144,654	16.4
Hand-pump boreholes	6,277,037	48.0
Protected wells	797,707	6.1
Unprotected sources	3,478,525	26.6
Total	13,077,161	100

Source: Malawi National Statistical Office, 2009

Table 3 shows that the improved water sources that were used by most people in Malawi in 2008 were hand-pump boreholes and piped water supplies. The numbers of these improved water sources in 2014 were as shown in table 4.

Table 4: Types and numbers of mostly used improved water sources in Malawi in 2014

Water source	**Number**
Piped systems managed by the Water Boards	60
Piped systems managed by the Department of Water Supply	126
Hand-pump boreholes managed by the Department of Water Supply	43,157

Source: Malawi Ministry of Irrigation and Water Development, 2014

1.3.2 Institutional set-up for DWS in Malawi

Provision of drinking water supply services in Malawi is the responsibility of the Department of Water Supply Services in the Ministry of Water Development and Irrigation. The water supply services in Malawi are divided into two, namely; water supply to cities and towns, and water supply to semi-urban and rural areas. Water supply services provided to the cities and towns are managed by the state-owned companies called Water Boards. There are five Water Boards in Malawi, namely; Blantyre Water Board, Lilongwe Water Board, Central Region Water Board, Northern Region Water Board and Southern Region Water Board (Government of Malawi, 1995). On the other hand, water supply services provided to the semi-urban and rural areas are managed by community-based structures with support from the Department of Water Supply Services.

Regulation and control of abstraction of water from both surface and ground sources is the responsibility of the National Water Resources Authority (Government of Malawi, 2013) formerly known as the Water Resources Board (Government of Malawi, 1969). The Authority issues licences authorising entities to abstract the allocated amounts of water. The reporting lines for the institutions involved in the provision of DWS services in Malawi are shown in figure 1.

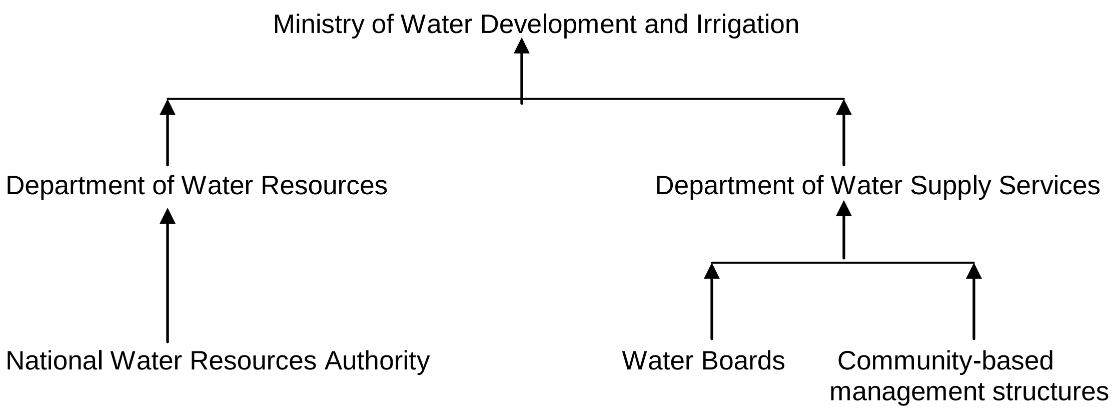


Figure 1: Organisational structure for DWS in Malawi

1.3.3 DWS targets and achievements in Malawi

Malawi has two major targets to achieve as regards drinking water supply. The first target is the Millennium Development Goal (MDG) number 7c. As a signatory of the United Nations (UN) Millennium Declaration, Malawi is required to achieve, among other targets, the MDG number 7c which requires countries to halve by the year 2015, the percentage of people who did not have sustainable access to safe drinking water in 1990 (UNGA, 2000; IOB and UNICEF, 2011). Malawi's MDG on drinking water supply is that 74% of the people should have access to safe water by 2015 (Malawi Ministry of Irrigation and Water Development, 2010).

The second target is to achieve universal access to improved water sources. Based on the African Water Vision for 2025, the Government of Malawi set itself a target of ensuring that 100% of the people in the country should have access to safe water by the year 2025 (Malawi Ministry of Irrigation and Water Development, 1994).

In order to achieve the set targets, the Government of Malawi employed the strategies of upgrading the existing DWS infrastructure and constructing new facilities. As such, implementation of projects for upgrading existing, and constructing new DWS infrastructure has been ongoing.

In terms of DWS coverage, there has been significant achievement in Malawi. The coverage moved from 41% in 1992 to 67% in 2002 (WHO/UNICEF, 2004). By 2006, the water supply coverage in Malawi reached 75% (Malawi National Statistical Office, 2006a), thereby achieving its MDG for water, almost a full decade ahead of the target date (Foster and Shkaratan, 2011). The DWS coverage kept increasing such that by 2010, 83% of the people in Malawi had access to improved water sources (UNICEF/WHO, 2012). If this trend continues, Malawi will achieve its target of universal access to improved water sources by the year 2018, seven years ahead of the target year of 2025.

1.4 SUSTAINABILITY OF DWS SERVICES IN MALAWI

As indicated in section 1.3.3, in Malawi, DWS coverage increased from 41% in 1992 to 83% in 2010. With 83% coverage in 2010, Malawi had the fifth highest DWS coverage in the Sub-Saharan Africa. The highest was Mauritius with 99% coverage. The second was Namibia with 93% coverage. The third and fourth were South Africa and Ghana with 91% and 86% coverage respectively (UNICEF/WHO, 2012).

While 83% DWS coverage in Malawi is quite good compared to other countries in the Sub-Saharan Africa, the quality and quantity of water supplied in Malawi deteriorate as time passes after commissioning of the water supply systems. Some rural piped DWS systems that used to supply safe water, no longer do so (World Bank, 2011). For instance, the results from the water quality surveillance conducted in 2009 in 10 rural DWS systems located in different parts of Malawi (summarised in table 5) showed that, on average, 86% of the samples collected from different places in the 10 areas were of contaminated water (Malawi Ministry of Irrigation and Water Development, 2009). As regards the situation in the individual DWS systems, it was noted that all the samples (100%) from 8 of the 10 DWS systems were of contaminated water, while 80% and 64% of the samples from the ninth and tenth DWS systems respectively were of contaminated water. The results from the water quality surveillance are in table 5.

Table 5: Number of samples with contaminated water

Water supply system number	Number of samples tested	Number of samples with contaminated water	% of samples with contaminated water
1	2	2	100
2	2	2	100
3	2	2	100
4	4	4	100
5	2	2	100
6	1	1	100
7	1	1	100
8	5	5	100
9	5	4	80
10	11	7	64
Total	35	30	86

Source: Malawi Ministry of Irrigation and Water Development, 2009

The results in table 5 mean that most people served by the studied systems were provided with unsafe water, when the systems were supposed to supply safe water. Most of such people ended up suffering from water-borne diseases (Hunter et al, 2009; Malawi Ministry of Health, 2007 to 2011).

It is noted that 3% of the patients that visited hospitals in Malawi between 2007 and 2011 suffered from water-borne diseases as shown in table 6.

Table 6: Prevalence rates of water-borne diseases in Malawi

Year	2007	2008	2009	2010	2011	Average
Prevalence rate (%)	3	3	3	3	3	3.0

Source: Malawi Ministry of Health, 2007 to 2011

It should be noted that 3.0% average prevalence rate of water-borne diseases in Malawi signals a problem with safety of the water used. Results from a worldwide study by Pruss-Ustun et al (2008) show that prevalence rate of water-borne diseases where people use unsafe water account for an average of 3.5% of all illnesses. Based on this finding, the average prevalence rate of water-borne diseases in Malawi, where 83% of the people have access to improved water sources, should have been about 0.6% and not 3.0%. The high prevalence rate of water-borne diseases suggests that most people in Malawi use unsafe water despite the water supply coverage being at 83%. As such, investigation will be conducted as part of this study to establish the quality of water available to the users in selected DWS systems in Malawi. However, to determine the extent of the problem, a pre-study survey was conducted. A short structured questionnaire was sent to the operators of 167 piped DWS systems in Malawi. The questionnaire was sent to the operators of 167 piped DWS systems out of a total of 186 systems because 19 of the systems were only about 2 years old at that time (2013). Sustainability of DWS services in the 2-year old systems could not conclusively be interpreted as showing that the DWS services would continue being sustainable for a long time. Rather the sustainability of the DWS services could be attributed to the fact that the systems were still new. As such, these systems were not included in the pre-study survey.

The results from the pre-study showed that one of the key reasons for the deteriorating quality of the water that is supplied is that the existing water treatment facilities, especially for rural water supply systems, do not have capacity to treat raw water, whose quality has deteriorated over the years (World Bank, 2011). The operators observed that quality of raw water in 42% of the sources had deteriorated over the years.

As indicated above, the other parameter of the water supply services that deteriorates with passage of time in Malawi is the quantity of water supplied. Information from 167 piped DWS systems in Malawi shows that the quantity of water available for supply to the users in 85% of the systems is less than the Government of Malawi recommended quantity of 36 litres per person per day. Consequently, water supply to the users is either intermittent or the flows from the taps are so low that it takes a long time to fill a container. Low water flows from the taps occur mostly in the rural areas.

For the urban areas, the challenge is mainly water supply intermittency. The average number of hours per day that water is available to the users in the urban areas is less than the planned 24 hours (World Bank, 2011). The results from a consumer survey conducted by the Ministry of Water Development and Irrigation in 2013 in 8 areas (summarised in table 7) showed that, on average, water was available to the users in 13 hours per day (Malawi Ministry of Water Development and Irrigation, 2013). In some areas, water was available only for 6 hours per day. The results from the consumer survey are provided in table 7.

Table 7: Number of hours that water was available in some WSSs in Malawi

Name of water supply system	Number of hours that water was available per day
Balaka	9
Blantyre	6
Chikhwawa	13
Mponela	16
Lilongwe	14
Mzimba	20
Mzuzu	15
Zomba	11
Average	13

Source: Malawi Ministry of Water Development and Irrigation, 2013

One reason for the decreasing quantity of water supplied to the users in Malawi is high non-functionality level of some drinking water supply systems. A study conducted by WaterAid established that 31% of the water points in Malawi were not functional in 2007.

The other reasons for the decreasing quantity of water supplied to the users in Malawi, based on the information from 167 piped DWS systems assessed in the pre-study survey, are that:

a. 81% of the DWS systems operated beyond their useful life period without being upgraded. As a result, the systems were not able to produce the required quantities of potable water because the required quantities had exceeded the capacities of the existing systems; and
b. Quantity of raw water in 43% of the sources had decreased with passage of time to the extent that the available quantity was less than the amount required to produce adequate potable water.

The above discussions show that sustainability of DWS services in Malawi is affected by a number of factors. Such factors, which have been identified at this stage of the study, include:

a. Functionality level of water supply systems;
b. Capacity of water supply systems to produce and supply adequate water;
c. Capacity of water supply systems to produce safe water;
d. Quantity of available raw water; and
e. Quality of raw water.

Since these may not be the only factors that affect sustainability of water supply services, investigation will be conducted as part of this study to determine a holistic set of factors that affect sustainability of DWS services in Malawi.

1.5 JUSTIFICATION FOR THIS RESEARCH

A close look at the factors identified at this stage of the study as affecting sustainability of the DWS services in Malawi (section 1.4) shows that managing some factors and not other factors will result in DWS services which are not sustainable. For example, ensuring that the water supply system functions as intended (i.e. no part of the system becomes non-functional) is not enough if the raw water quantity is not adequate. This is the case because the infrastructure will not be able to produce the required amount of water due to non-availability of raw water which is a key input. Conversely, sustainability of available amount of raw water is not enough if the infrastructure is in a dilapidated state. This is so because the dilapidated infrastructure will not be able to produce potable (processed) water in the required quantity even though the raw water might be available. This shows the need to manage all the factors that affect sustainability of DWS services in Malawi.

In terms of the factors, a number of studies have been conducted to identify the factors that affect sustainability of DWS services. When the factors from different studies are put together, the list is long and almost exhaustive. However, in most cases, not all the factors are managed in a particular water supply system (WSS). Instead, different combinations of some of the factors are managed in different WSSs (Lockwood, 2003; Masduqi et al, 2009; McConville and Mihelcic, 2007; WaterAid, 2010). Additionally, the factors that are managed are not necessarily the root causes of the decrease of the quantity of water supplied or of the deterioration of the water quality. The consequence of this, as it will be noted in section 2.6.3, is that not all the aspects required for sustainability of the quantity and quality of drinking water are maintained. As a result, the quantity and quality of drinking water in Malawi deteriorate as time passes after commissioning of the water supply systems because some of the aspects required for their sustainability are not maintained (Malawi Ministry of Irrigation and Water Development, 2009; Malawi Ministry of Water Development and Irrigation, 2013; WaterAid, 2007; World Bank, 2011).

In addition, it is noted in the body of knowledge for DWS management that sets of factors that have been studied in detail contain few factors. It is further noted that the few factors have not been studied as interactions. This has been the case despite that for over a decade now, there has been an advice in the literature that to achieve service sustainability, there is need to group the factors and manage their interactions (Belassi and Tukel, 1996; Clarke, 1998; King, 1996). There is, therefore, a need to study all the factors acting together as interactions. It is important to study all the factors because each factor has influence on service sustainability. Management of some factors and not other factors results in certain aspects required for sustainability not being maintained, and that failure of any one aspect of sustainability renders DWS services not sustainable (Abrams, 1998; Khan, 2000; Lockwood and Smits, 2011).

Interactions of the factors show combined effects (symptoms) as well as root causes (Duffy et al, 2012). As such, the advice in the literature that sustainability of services can only be achieved by managing interactions of the factors simply means that services can only be sustained by addressing combined effects of the factors through managing the related root causes. After all, it is argued that once corrective measures are taken on the root causes, the likelihood of recurrence of the sustainability failure will be minimised (Dew, 1991; Doggett, 2005).

Thus, the justification for this research is the need to fill the gap identified in the body of knowledge for project management that the factors that affect sustainability of services should be managed as interactions. Since in most cases, one interaction includes a number of factors, there will be few interactions that will need to be managed. As such, it will be easy to manage all the factors that affect sustainability of DWS services. Therefore, management of all the factors as interactions will resolve the challenge of managing the factors in isolation which is complex. In addition, management of all the factors will ensure maintenance of all aspects required for sustainability of DWS services. This will result in sustainable DWS services.

The study concentrated on the piped DWS systems despite that it is the hand-pump boreholes which supply drinking water to most people in Malawi (section 1.3.1). This is the case because the piped DWS systems in Malawi have a higher non-functionality rate than the hand-pump boreholes. For example, in a study by WaterAid in 2007, it was noted that 51% of the water points for the piped DWS systems were non-functional while only 21% of the hand-pump boreholes were non-functional. This calls for a quick solution to improve the functionality rate for the piped DWS systems in Malawi.

The other reason for the study being on the piped DWS systems and not on the hand-pump boreholes is that the piped DWS systems offer higher levels of services than hand-pump boreholes (Sara and Katz, 1998). This is the case in that the water points for the piped DWS systems are located within people's homes or nearby places as a result of extensive distribution pipe networks. Due to short distances to such water points, people collect and use adequate quantities of water which facilitate easy realisation of the benefits of using potable water (Esrey et al, 1996; Howard and Bartram, 2003). This is different with people who travel long distances to hand-pump boreholes to fetch water. In such instances, people normally collect and use inadequate safe water (Carter et al, 1999). Therefore, provision of drinking water through piped systems makes it easier for the health and other benefits to be realised. Studying how to facilitate sustainability of DWS services from the piped systems will lead to improved sustainability of DWS services from the piped systems which will in turn make realisation of the benefits from DWS services even easier.

1.6 PROBLEM STATEMENT

From the discussions in section 1.4, it will be noted that the problem at hand is that the quantity and quality of drinking water (DWS services) in Malawi decreases and deteriorates respectively as time passes after commissioning of the water supply systems. Water provided by some piped DWS systems in the rural areas is no longer safe for human consumption, and the quantity of water from some water supply systems is no longer adequate for supply per capita. As such, the research problem is that:

"The quantity and quality of drinking water (DWS services) in Malawi decreases and deteriorates respectively as time passes after commissioning of the water supply systems"

It is noted that the decrease and deterioration of the quantity and quality of drinking water respectively could be because not all the factors are managed, and those that are managed are not necessarily the root causes of the deterioration of the DWS services (sections 1.4 and 1.5). This view is based on the fact that most problem solving models recommend that it is the root causes that should be managed in order to solve problems completely (Rebori, 1997; Restructuring Associates Incorporation, 2008). Therefore, the key question to be answered by this research is:

“Does management of the root causes of sustainability failure of DWS services improve sustainability of DWS services in Malawi?”

1.7 AIM AND OBJECTIVES OF THE INVESTIGATION

To establish whether or not management of the root causes of sustainability failure of DWS services improve sustainability of DWS services in Malawi, there is need to compare sustainability of DWS services where the root causes are managed and where they are not managed. However, review of the literature has shown that the root causes of sustainability failure of DWS services have not yet been identified. This means that before the comparison can be done, there is need to identify the root causes. Therefore, the aim of this research is to identify the root causes of sustainability failure of DWS services in Malawi, evaluate the outcomes of managing the root causes on sustainability of DWS services, and develop a framework for managing the identified root causes. The study’s objectives are:

a. To assess sustainability of the quantity and quality of water available to the users in the selected DWS systems in Malawi;
b. To identify the factors that affect sustainability of DWS services;
c. To establish relationships that exist amongst various factors that affect sustainability of DWS services;
d. To find out the factors which need to be managed for sustainability of DWS services; and
e. To develop a framework for holistic management of factors for sustainability of DWS services in Malawi.

1.8 RESEARCH FOCUS AND BOUNDARIES

Holistic and life cycle approaches were followed in this study. Under holistic approach, a DWS system was studied as a whole including water sources, infrastructure, capacity to operate the infrastructure, and expectations of stakeholders from provision of drinking water. This approach is supported by Kenel and Whitherspoon (2005) who state that DWS involves water source protection, water treatment and all activities until the water is delivered at the consumer’s tap. All the issues related to these elements, that affect sustainability of DWS services, were studied i.e. the study covered nearly all potential factors that can affect DWS service sustainability. This was necessary to ensure that all aspects of DWS service sustainability would be maintained.

In addition, under life cycle approach, all the issues in all the phases of a project that affect sustainability of DWS services were studied. This was necessary to address all the issues in the preceding phases which may affect DWS service sustainability in the subsequent phases (Klöpffer, 2003; Lim and Mohamed, 1999).

1.9 RESEARCH PERSPECTIVE

This study was based on the perceptions of the service providers and water users. The perceptions of the water users and the service providers are important in that two of the key factors for a service to be sustainable are that the users should be satisfied with the service (Agarwal and Rathod, 2006; Pinto and Slevin, 1994), and that the service provider's expectations should be realised (Al-Tmeemy et al, 2011).

1.10 STRUCTURE OF THE THESIS

In addition to this introductory chapter (chapter 1), this thesis has chapters 2 to 5. The thesis also has appendices A and B. Chapter 2 provides a critical review of the literature on service sustainability. The review is based on books, journal articles, conference papers, published case studies and other literature. The chapter outlines the factors and frameworks for sustainability of DWS services. On the basis of the reviewed literature, gaps have been established and research questions have been formulated accordingly.

Chapter 3 provides research methodology for the study. Bases for selecting a particular paradigm and techniques for data collection and analysis have been provided. In addition, chapter 3 provides criteria for selecting cases and details of the selected cases. The chapter also outlines the participants in the research study.

Chapter 4 is where the findings of the study are presented. Based on the findings, solutions for facilitating sustainability of DWS services in Malawi have been proposed. The chapter also presents a holistic framework which has been developed in this research for managing the factors that affect sustainability of the piped DWS services in Malawi.

Chapter 5 provides a summary of the findings of this research and provides recommendations on how to deal with the findings so that DWS services should be sustainable. Contributions made by the study to DWS management are also presented in the chapter. Finally, chapter 5 outlines the required further work to enhance the findings of this research.

As regards appendices, Appendix A contains instruments used to collect data for this research while Appendix B contains a journal paper published in the *Journal of Sustainable Development in Africa*.

Chapter summary

Chapter 1 has set this research in context by providing information about the importance of DWS, and the current DWS coverage globally, in the Sub-Saharan Africa and in Malawi. Details on management and sustainability of DWS services in Malawi have also been provided. The chapter has also outlined the research problem, aim and objectives.

CHAPTER TWO - LITERATURE REVIEW

Introduction

This chapter presents a critical review of the literature on sustainability of DWS services. The definition and attributes of DWS service are presented in the chapter. The chapter also outlines the factors and frameworks for service sustainability with particular emphasis on sustainability of DWS services. On the basis of the reviewed literature, gaps have been established and research questions have been formulated accordingly.

2.1 DRINKING WATER SUPPLY SERVICES

A service is the provision of a benefit (Lockwood and Smits, 2011). DWS service, which is the subject for this research, is defined as a flow of water to the users (Lockwood and Smits, 2011). There are a number of parameters that are used to measure whether or not a DWS service is satisfactory. The parameters include: (i) distance to a water source; (ii) time taken to collect water; (iii) number of people using one water source; (iv) number of hours per day during which water is supplied; (v) quantity of water supplied; (vi) pressure of water supplied; (vii) quality of water supplied; (viii) location of water point; (ix) continuity of water supply; and (x) type of connection i.e. whether it is a house connection, yard tap or communal water point (Bhandari and Grant, 2007; Carter et al, 1999; Howard and Bartram, 2003; Lockwood and Smits, 2011; Sara and Kartz, 1998).

It will be noted that apart from ‘quality of water supplied’, the rest of the parameters listed above are factors for facilitating ‘availability of adequate water to the users’. This shows that the main indicators of whether or not a drinking water supply (DWS) service is satisfactory are two; (i) safety, and (ii) adequacy of drinking water. The two parameters are sufficient as these are all that is required for the main purpose of DWS (i.e. to maintain and/or improve public health) to be achieved (AfDB, 2008; Carter et al, 1999; Howard and Bartram, 2003). On this basis, the working definition of DWS service for this research is a flow of water of a particular quality and quantity.

In terms of the recommended minimum requirements, in a study conducted by Carter et al (1999), it was found out that most countries consider 20 litres per capita per day as the minimum amount of water that should be used.

As regards quality, water is said to be safe for human consumption if it satisfies physical, organoleptic, chemical and biological requirements (Malawi Standards Board, 2005). While this is the case, the most common and widespread health risk associated with drinking water is microbial contamination (WHO, 2006). As such, and due to limited financial resources available for this research, microbial contamination - specifically faecal contamination - will be considered as a sole measure of the safety of water for human consumption. After all, the disease burden caused by physical, organoleptic and chemical contamination (non-diarrheal diseases) is far below that caused by microbial contamination (diarrheal diseases) (Fewtrell et al, 2006). The study by Carter et al (1999) established that most countries consider water with faecal coliforms not more than 10 per 100 millilitres as safe.

Other researchers, however, have their own recommendations. For example, Gleick (1996) states that the minimum quantity of water used should be 50 litres per capita per day in order for health benefits to be realised. Similarly, WHO (2006) states that the number of coliforms in drinking water should be zero.

For Malawi, the minimum requirements for drinking water are as follows:

a. Quantity of water used should not be less than 36 litres per capita per day (Malawi Ministry of Irrigation and Water Development, 1994); and
b. Quality of water should be such that the number of faecal coliforms per 100 millilitres of water should not be more than 10 in 99% of the samples (Malawi Standards Board, 2005).

As indicated in section 1.4, this research was conducted because these minimum requirements were not satisfied in some of the DWS systems in Malawi as time passed after commissioning of the water supply systems.

2.2 SUSTAINABILITY

The word ‘sustainability’ is derived from the Latin word ‘sustinere’ which means to uphold. Similarly, the English word ‘sustain’ means ‘maintain’ or ‘endure’ (Onions, 1964). This shows that the meaning of the word ‘sustain’ is not different from the meaning of the original Latin word ‘sustinere’. The basic meaning of the word is ‘maintain’.

As regards the technical meaning of the word ‘sustainability’, there is a broad range of definitions in the literature. While most definitions are similar, there are some which are different. The reason why some definitions are different is that sustainability has normative connotations i.e. perception of sustainability by different people or groups of people is based on the relative value of achieving their various goals (Hodgkin, 1994). As such, different organizations look at sustainability from different perspectives. Examples of the perspectives from which sustainability is looked at are technical performance, health benefits, empowerment, social equity or environmental protection, among others (Lockwood, 2003).

Since all aspects required for sustainability have to be maintained otherwise failure of any one of them will render a project not sustainable (Abrams, 1998; Khan, 2000), the definition by Bamberger and Cheema (1990) has been adopted for this research. Bamberger and Cheema (1990) define sustainability as continuous delivery of benefits for a long time. This definition is based on the ultimate goal of a project of 'providing some benefits' (Lockwood, 2003) other than particular perspectives.

The aspects that need to be maintained for sustainability of benefits are technical, managerial, policy, economic, financial, social, institutional, environmental and climatic in nature (Griffiths, 2007; Harvey and Reed, 2004; Khan, 2000).

It should be noted that for benefits to be maintained, there is need for services to be sustainable (Harvey and Reed, 2003; Khan, 2000; Parry-Jones et al, 2001; WELL, 1998). As indicated in the preceding sections, this research is about sustainability of DWS services with regard to both quality and quantity of drinking water.

2.3 SERVICE SUSTAINABILITY

In line with the definition of sustainability adopted in section 2.2, service sustainability is defined here as continued provision of services to the users. Specifically for DWS services, Carter et al (1999) define DWS service sustainability as continued flow of water at the same rate and quality as per the design of the supply system. This is the working definition of DWS service sustainability for this study.

It is important that services should be sustainable. Firstly, some services like DWS can only accomplish their purposes if they are available all the time (Sanders and Fitts, 2011). For example, if safe water is not available for some time, people will be forced to use water from unsafe sources. Such people end up suffering from water borne diseases implying that the provided DWS has failed to accomplish its main purpose of maintaining and/or improving public health (Bostoen, 2005; UNICEF and WHO, 2012).

Secondly, sustainable services are cost-effective (Carter and Rwamwanja, 2006). This is the case because sustainable services lead to realisation of benefits for a long time which in most cases makes the accumulated benefits to be more than the costs.

In addition, where services are sustainable, follow-on investments are made only after expiry of the design period of the project (Ashley, 1986). This ensures that the costs at the end of the project remain almost as estimated at the time of project appraisal because there are no unplanned works implemented. This results in a project that remains cost-effective as projected at the time of project appraisal.

Thirdly, it is very easy to achieve targets like Millennium Development Goals with sustainable services (Haysom, 2006). This is the case because the existing interventions continue providing benefits to the existing beneficiaries while new interventions provide benefits to the new beneficiaries thereby increasing the number of beneficiaries (Carter and Rwamwanja, 2006).

Fourthly, sustainable services improve user dependency on the services. Users stop using alternative services if there is a sustainable service. For example, where availability of safe drinking water is sustainable, people stop using alternative water sources. On the other hand, if safe DWS is not sustainable, people are forced to continue using or to revert back to the unimproved water sources (Harvey and Reed, 2006).

Fifthly, sustainable services encourage financiers and/or project owners to come up with additional interventions. Because of the positive impacts that sustainable services bring, financiers and/or project owners are encouraged to come up with additional interventions so that more benefits can be realised.

Finally, sustainable services encourage communities to participate in future projects. For example, by meeting the community expectations raised during project design through sustainable services, people are encouraged to participate in future projects (MacDonald, 2005).

2.4 SERVICE SUSTAINABILITY FACTORS FOR DWS

A service sustainability factor is an influence which affects sustainability of a service. There are a number of factors that affect sustainability of services. The following subsections outline service sustainability factors with particular emphasis on sustainability factors for DWS services. The factors have been identified by following holistic and life cycle approaches in which nearly all potential factors related to water sources, infrastructure, capacity to operate the infrastructure, and expectations of stakeholders from provision of drinking water, in all phases of a project, have been identified.

2.4.1 Sustainability factors for services other than DWS services

A list in table 8 contains factors which have been identified as affecting sustainability of some services which are not DWS. The factors have been identified by the researchers shown in table 8 as affecting sustainability of services in the energy, transport, health, mining, aerospace engineering, and building sectors, among others.

Table 8: A list of sustainability factors for services other than DWS services

No.	Sustainability factors	Authors														
		Avots, 1969	Kerzner, 1987	Morris and Hough, 1987	Pinto and Slevin, 1988	Sanvido et al, 1992	Clarke, 1995	Munns and Bjeirmi, 1996	Lopes and Flavell, 1998	Fowler and Walsh, 1999	Kwak, 2002	Abdullah and Ramly, 2006	Griffiths, 2007	Struyk, 2007	Khang and Moe, 2008	Al-Tmeemy et al, 2011
1	Appropriate technology										√					
2	Stability of operating environment e.g. economic status										√			√	√	
3	Continual evaluation and improvement				√											
4	Climate change impacts												√			
5	Troubleshooting				√											
6	Lessons from past projects/organisational learning													√		
7	Realistic objectives						√	√								
8	Environmental considerations								√							
9	Social considerations								√							
10	Assessment and addressing of risks			√												
11	Organisational structure adaptation to a project		√													
12	Organisational culture adaptation to a project		√													
13	Health and safety measures					√										
14	User involvement									√						
15	Involvement of senior managers in projects				√					√						
16	Human resource management											√				
17	Project owner requirements	√														
18	Realisation of service provider expectations															√

Source: Author

Being able to affect sustainability of various other services as indicated above, the factors in table 8 can potentially affect sustainability of DWS services. This view is reinforced by the notion that a number of factors are common to most types of projects (Bryde, 2008; Saucer et al, 2009). As such, in section 2.4.4, these factors will be combined with DWS service sustainability factors. The combined factors will form a list of potential factors that can affect sustainability of DWS services in Malawi.

2.4.2 Sustainability factors for DWS services globally

Many researchers in the subject area of DWS management have come up with a number of DWS service sustainability factors. A list in table 9 contains sustainability factors for DWS services in countries other than Malawi.

Table 9: A list of sustainability factors for DWS services in countries other than Malawi

No.	Sustainability factors	Authors and countries of study																																						
		Roark, Yacoob and Roark, 1989 (Botswana)	Hodgkin, 1994 (Lesotho)	Abrams, 1998 (South Africa)	Sara and Katz, 1998 (Benin, Uganda)	ADB-ADF, 1998 (Kenya)	WSP, 1998 (India)	Carter, Tyrrel and Howsam, 1999 (Zimbabwe)	Aini et al, 2001 (Malaysia)	Parry-Jones et al, 2001 (Mozambique)	Sonuga, Aliboh and Oloke, 2002 (Nigeria)	Mwanza, 2003 (Zambia)	Harvey and Reed, 2003 (Ghana, Zambia)	Lockwood, 2003 (India, Ghana)	Mukherjee and van Wijk, 2003 (Tanzania)	Harvey and Reed, 2004 (Kenya)	WHO and UNICEF, 2004 (Peru)	Kenel and Whitherspoon, 2005 (USA)	Arnell and Delaney, 2006 (England & Wales)	Butler and Memon, 2006 (United Kingdom)	Carter and Rwamwanja, 2006 (Uganda)	UNDP-WSP, 2006 (Ghana, Uganda)	Aini et al, 2007 (Malaysia)	Bhandari and Grant, 2007 (Nepal)	Morita-Lou and Waters, 2008 (Tanzania)	Carter and Parker, 2009 (Ethiopia, Sudan)	Harvey, 2009 (Kenya, Uganda, Zambia)	Montgomery, Bartram and Elimelech, 2009 (Kenya)	Rietveld et al, 2009 (South Africa)	Sharma and Quintanilla, 2009 (Bolivia)	Bruggen et al, 2010 (Democratic Republic of Congo)	Hunter et al, 2010 (Bangladesh)	Jenicek et al, 2010 (United States of America)	WaterAid, 2010 (Tanzania, Cambodia)	Yigitcanlar and Dur, 2010 (Australia)	Harvey, 2011 (Uganda, Kenya, Ghana)	Man et al, 2011 (Hong Kong)	Mimrose et al, 2011 (Sri Lanka)	Carden and Armitage, 2013 (South Africa)	Tadesse et al, 2013 (Ethiopia)
1	Appropriate technology e.g. water supply system that the benefiting community can sustain	√	√										√			√									√		√	√								√				
2	Quality of project designs i.e. specifications from designs		√					√							√									√												√				
3	Capacity to operate infrastructure	√	√				√	√		√					√	√									√			√								√				
4	Capacity to maintain infrastructure	√	√				√	√		√					√	√									√			√								√				
5	Stability of operating environment e.g. economic status												√			√															√	√								
6	Stakeholder participation		√												√										√															
7	Involvement of trained personnel	√	√		√	√								√	√							√			√															
8	Involvement of motivated personnel	√	√		√	√								√	√							√			√															
9	Continual evaluation and improvement		√													√												√												
10	Climate change impacts																	√								√							√		√				√	
11	Management type of water supply system e.g. decentralised management, autonomous entity		√		√							√	√			√								√	√		√			√		√				√				
12	Project sponsor regulations		√										√																											
13	Quality of infrastructure		√		√			√							√																							√		
14	Demand-responsive approach				√										√													√												

No.	Sustainability factors	Authors and countries of study																																						
		Roark, Yacoob and Roark, 1989 (Botswana)	Hodgkin, 1994 (Lesotho)	Abrams, 1998 (South Africa)	Sara and Katz, 1998 (Benin, Uganda)	ADB-ADF, 1998 (Kenya)	WSP, 1998 (India)	Carter, Tyrrel and Howsam, 1999 (Zimbabwe)	Aini et al, 2001 (Malaysia)	Parry-Jones et al, 2001 (Mozambique)	Sonuga, Aliboh and Oloke, 2002 (Nigeria)	Mwanza, 2003 (Zambia)	Harvey and Reed, 2003 (Ghana, Zambia)	Lockwood, 2003 (India, Ghana)	Mukherjee and van Wijk, 2003 (Tanzania)	Harvey and Reed, 2004 (Kenya)	WHO and UNICEF, 2004 (Peru)	Kenel and Whitherspoon, 2005 (USA)	Arnell and Delaney, 2006 (England & Wales)	Butler and Memon, 2006 (United Kingdom)	Carter and Rwamwanja, 2006 (Uganda)	UNDP-WSP, 2006 (Ghana, Uganda)	Aini et al, 2007 (Malaysia)	Bhandari and Grant, 2007 (Nepal)	Morita-Lou and Waters, 2008 (Tanzania)	Carter and Parker, 2009 (Ethiopia, Sudan)	Harvey, 2009 (Kenya, Uganda, Zambia)	Montgomery, Bartram and Elimelech, 2009 (Kenya)	Rietveld et al, 2009 (South Africa)	Sharma and Quintanilla, 2009 (Bolivia)	Bruggen et al, 2010 (Democratic Republic of Congo)	Hunter et al, 2010 (Bangladesh)	Jenicek et al, 2010 (United States of America)	WaterAid, 2010 (Tanzania, Cambodia)	Yigitcanlar and Dur, 2010 (Australia)	Harvey, 2011 (Uganda, Kenya, Ghana)	Man et al, 2011 (Hong Kong)	Mimrose et al, 2011 (Sri Lanka)	Carden and Armitage, 2013 (South Africa)	Tadesse et al, 2013 (Ethiopia)
15	Performance by consultants																								√			√												
16	Performance by contractors																								√			√												
17	Performance by suppliers																								√			√												
18	User satisfaction with a service	√	√					√							√																									
19	Gender and poverty focus	√													√										√															
20	Lessons from past projects/organisational learning																√																							
21	Achievement of benefits by users e.g. health and economic benefits	√																																						
22	Protection of water source/catchment area							√	√					√											√													√		√
23	Quantity of raw water																	√	√				√						√			√	√	√					√	
24	Quality of raw water																	√	√				√										√	√					√	
25	Spare parts supply															√						√			√															
26	Rewards for good operation																							√																
27	Rewards for good maintenance																							√																
28	Supervision by superiors e.g. district authorities, government ministry																							√																
29	Proper handover of new infrastructure																							√																
30	Continuous upgrading of infrastructure e.g. extension of pipe network					√																																		
31	Level of water loss					√			√										√																				√	

No.	Sustainability factors	Authors and countries of study																																						
		Roark, Yacoob and Roark, 1989 (Botswana)	Hodgkin, 1994 (Lesotho)	Abrams, 1998 (South Africa)	Sara and Katz, 1998 (Benin, Uganda)	ADB-ADF, 1998 (Kenya)	WSP, 1998 (India)	Carter, Tyrrel and Howsam, 1999 (Zimbabwe)	Aini et al, 2001 (Malaysia)	Parry-Jones et al, 2001 (Mozambique)	Sonuga, Aliboh and Oloke, 2002 (Nigeria)	Mwanza, 2003 (Zambia)	Harvey and Reed, 2003 (Ghana, Zambia)	Lockwood, 2003 (India, Ghana)	Mukherjee and van Wijk, 2003 (Tanzania)	Harvey and Reed, 2004 (Kenya)	WHO and UNICEF, 2004 (Peru)	Kenel and Whitherspoon, 2005 (USA)	Arnell and Delaney, 2006 (England & Wales)	Butler and Memon, 2006 (United Kingdom)	Carter and Rwamwanja, 2006 (Uganda)	UNDP-WSP, 2006 (Ghana, Uganda)	Aini et al, 2007 (Malaysia)	Bhandari and Grant, 2007 (Nepal)	Morita-Lou and Waters, 2008 (Tanzania)	Carter and Parker, 2009 (Ethiopia, Sudan)	Harvey, 2009 (Kenya, Uganda, Zambia)	Montgomery, Bartram and Elimelech, 2009 (Kenya)	Rietveld et al, 2009 (South Africa)	Sharma and Quintanilla, 2009 (Bolivia)	Bruggen et al, 2010 (Democratic Republic of Congo)	Hunter et al, 2010 (Bangladesh)	Jenicek et al, 2010 (United States of America)	WaterAid, 2010 (Tanzania, Cambodia)	Yigitcanlar and Dur, 2010 (Australia)	Harvey, 2011 (Uganda, Kenya, Ghana)	Man et al, 2011 (Hong Kong)	Mimrose et al, 2011 (Sri Lanka)	Carden and Armitage, 2013 (South Africa)	Tadesse et al, 2013 (Ethiopia)
32	Full cost recovery tariffs					√																																√		
33	Collection of all generated revenue					√																										√						√		
34	Equity in distribution of water supply services																								√															
35	Operation cost																								√															
36	Maintenance cost																								√															
37	Rate and extent of breakdown of infrastructure	√						√																																
38	Population growth rate																√	√													√		√						√	
39	Developmental improvements																√	√															√						√	
40	Efficiency of using water resources																								√															
41	Equity in distribution of water resources																		√														√							
42	Institutional set-up		√																																	√				
43	Community participation										√																													
44	Post-project implementation external support		√					√									√					√			√			√				√								
45	Continued use of supplied water			√																																				
46	Growth of water demand																		√														√				√			
47	Age of infrastructure																																√				√			
48	Continued training													√																√										

No.	Sustainability factors	Authors and countries of study																																						
		Roark, Yacoob and Roark, 1989 (Botswana)	Hodgkin, 1994 (Lesotho)	Abrams, 1998 (South Africa)	Sara and Katz, 1998 (Benin, Uganda)	ADB-ADF, 1998 (Kenya)	WSP, 1998 (India)	Carter, Tyrrel and Howsam, 1999 (Zimbabwe)	Aini et al, 2001 (Malaysia)	Parry-Jones et al, 2001 (Mozambique)	Sonuga, Aliboh and Oloke, 2002 (Nigeria)	Mwanza, 2003 (Zambia)	Harvey and Reed, 2003 (Ghana, Zambia)	Lockwood, 2003 (India, Ghana)	Mukherjee and van Wijk, 2003 (Tanzania)	Harvey and Reed, 2004 (Kenya)	WHO and UNICEF, 2004 (Peru)	Kenel and Whitherspoon, 2005 (USA)	Arnell and Delaney, 2006 (England & Wales)	Butler and Memon, 2006 (United Kingdom)	Carter and Rwamwanja, 2006 (Uganda)	UNDP-WSP, 2006 (Ghana, Uganda)	Aini et al, 2007 (Malaysia)	Bhandari and Grant, 2007 (Nepal)	Morita-Lou and Waters, 2008 (Tanzania)	Carter and Parker, 2009 (Ethiopia, Sudan)	Harvey, 2009 (Kenya, Uganda, Zambia)	Montgomery, Bartram and Elimelech, 2009 (Kenya)	Rietveld et al, 2009 (South Africa)	Sharma and Quintanilla, 2009 (Bolivia)	Bruggen et al, 2010 (Democratic Republic of Congo)	Hunter et al, 2010 (Bangladesh)	Jenicek et al, 2010 (United States of America)	WaterAid, 2010 (Tanzania, Cambodia)	Yigitcanlar and Dur, 2010 (Australia)	Harvey, 2011 (Uganda, Kenya, Ghana)	Man et al, 2011 (Hong Kong)	Mimrose et al, 2011 (Sri Lanka)	Carden and Armitage, 2013 (South Africa)	Tadesse et al, 2013 (Ethiopia)
49	Incentives for stakeholders							√																								√								
50	Political support/ interference													√																	√	√								
51	Geographic focus																				√																			
52	Supply of maintenance tools				√																																			
53	Infrastructure that works as required																												√											
54	Availability/adequacy of supplies e.g. power supply																												√											
55	Appropriateness of policies																															√								
56	Wasteful usage of water								√																															
57	Leaking water supply facilities																						√																	
58	Availability of alternative water sources																																					√		
59	Activities taking place in water catchment area																																					√		
60	Water demand management																			√																				

Source: Author

The factors in table 9 are sustainability factors for DWS services in various countries other than Malawi. However, if different types of projects can be affected by some common factors (based on the notion that a number of factors are common to most types of projects (Bryde, 2008; Saucer et al, 2009)), there is a high chance that the factors that affect sustainability of DWS services in one geographical region can easily affect sustainability of DWS services in other geographical regions. For example, unavailability of adequate raw water which affects sustainability of DWS services in some parts of the United States of America also affects sustainability of DWS services in Malawi (Jenicek et al, 2010; UNCHS-Habitat, 1989). As such, the factors in table 9 are considered to have potential to affect sustainability of DWS services in Malawi. Therefore, in section 2.4.4, the factors in table 9 will be combined with the factors that affect sustainability of DWS services in Malawi. The combined factors will form a list of potential factors that can affect sustainability of DWS services in Malawi.

2.4.3 Sustainability factors for DWS services in Malawi

UNCHS-Habitat (1989) states that factors that lead to sustainability of DWS services in Malawi are user involvement, continual evaluation and improvement, perennial streams, supportive government policy, involvement of trained personnel, project infrastructure that works as required, simple project designs, appropriate technology, spare parts supply, and preventative maintenance. In addition, Foster and Shkaratan (2011) state that full cost recovery tariffs, collection of all generated revenue, and maintenance of water loss within acceptable levels can contribute to sustainability of DWS services in Malawi.

Vandalism of infrastructure has also been mentioned as a factor that affects sustainability of DWS services in Malawi (Baumann and Danert, 2008).

The above factors will be combined with those in tables 8 and 9 to form a list of potential factors that can affect sustainability of DWS services in Malawi.

2.4.4 Combining service sustainability factors

In this section, the sustainability factors for DWS services (table 9 and section 2.4.3) are combined with the sustainability factors for other services (table 8). The factors are combined because each one of them can potentially affect sustainability of DWS services in Malawi (Bryde, 2008; Saucer et al, 2009). In combining the factors, those that were split but refer to one main factor have been grouped together and called one name. For example, stakeholder participation, community participation and gender focus have been referred to as ‘involvement of appropriate stakeholders’. Similarly, full cost recovery tariffs, collection of all generated revenue, operation cost and maintenance cost have been referred to as ‘availability/use of adequate financial resources’.

In addition, other factors, which were too general, have been reworded so that they are specific and clear. For example, ‘environmental considerations’ have been changed to ‘environmental/natural condition of water catchment area’. With this synthesis, the number of factors has reduced from 76 as they appear in tables 8, 9 and section 2.4.3 to 63 factors. The synthesised and combined factors are in table 10.

Table 10: Combined list of conceptual service sustainability factors from the literature

CF1.	Type of technology	CF19.	Availability/adequacy of supplies e.g. power supply
CF2.	Quality of infrastructure	CF20.	Leaking water supply facilities
CF3.	Proper handover of new infrastructure	CF21.	Rewards to all people involved in provision of DWS services
CF4.	Infrastructure that works as required	CF22.	Involvement of trained personnel
CF5.	Continuous upgrading of infrastructure e.g. extension of pipe network	CF23.	Continued training
CF6.	Preventative maintenance	CF24.	Involvement of motivated personnel
CF7.	Rate of breakdown of infrastructure	CF25.	Human resource management
CF8.	Extent of breakdown of Infrastructure	CF26.	Organisational culture adaptation to a project
CF9.	Performance by consultants	CF27.	Realistic objectives
CF10.	Performance by contractors	CF28.	Stability of economic status of users
CF11.	Capacity to maintain infrastructure	CF29.	Supportive legislation/policies
CF12.	Capacity to operate infrastructure	CF30.	Population growth rate
CF13.	Performance by suppliers	CF31.	Developmental improvements
CF14.	Use of alternative water sources	CF32.	Equity in distribution of water resources
CF15.	Efficiency of using water resources	CF33.	Natural condition of water catchment area
CF16.	Vandalism of infrastructure	CF34.	Protection of water source
CF17.	Growth of water demand	CF35.	Quantity of raw water
CF18.	Age of infrastructure	CF36.	Quality of raw water
		CF37.	Perennial source of water

Source: Author

Table 10: continued

CF38. Social/economic activities in water catchment area	CF49. Climate change impacts
CF39. Involvement of appropriate stakeholders	CF50. Lessons from past projects/ organisational learning
CF40. User involvement	CF51. Troubleshooting
CF41. User satisfaction with a service	CF52. Safety of workers
CF42. Continued use of supplied water as expected at the design stage	CF53. Involvement of senior managers in a project
CF43. Achievement of benefits by users e.g. health and economic benefits	CF54. External support
CF44. Demand-responsive approach	CF55. Project owner requirements
CF45. Availability/use of adequate financial resources	CF56. Project sponsor regulations
CF46. Management arrangement (type) of water supply system	CF57. Supervision of subordinates
CF47. Spare parts supply	CF58. Level of water loss
CF48. Maintenance tools supply	CF59. Wasteful usage of water
	CF60. Water demand management
	CF61. Inter-community competitions
	CF62. Political support/interference
	CF63. Realisation of service provider expectations

Source: Author

All the factors in table 10 were taken, at this stage of the research, as potential factors that could affect sustainability of DWS services in Malawi. The factors that really affect sustainability of DWS services in Malawi would be identified through case studies.

2.5 RELATIONSHIPS AMONGST DWS SUSTAINABILITY FACTORS

One key relationship amongst the DWS service sustainability factors, which has been reported by many researchers, is that different groups of factors influence different types of aspects that affect sustainability of DWS services. The types of aspects that are affected by the factors are technical, managerial, policy, economic, financial, social, institutional, environmental and climatic (Griffiths, 2007; Harvey and Reed, 2004; Khan, 2000). The authors categorise the factors based on these aspects.

Harvey and Reed (2004) group the factors into 8 categories, namely; policy context, institutional arrangements, financial and economic issues, community and social aspects, technology and natural environment, spare parts supply, maintenance, and monitoring. Sugden (2003) came up with 5 categories, namely; managerial, social, financial, institutional and technical factors. On its part, WELL (1998) categorises service sustainability factors into 5 groups. The five groups are institutional, social, technical, environmental, and financial dimensions.

It will be noted from the above that the categories of service sustainability factors are similar amongst different authors. The only difference is that some authors are more specific than others, and other authors split categories into further categories. For example, Harvey and Reed (2004) came up with spare parts supply, maintenance, monitoring, and technology as some of the categories. It will be noted that these categories can easily be placed under certain main categories. For instance, spare parts supply is an institutional arrangement issue while maintenance and technology are technical issues. When the categories that can fall under other categories (sub-categories) are not considered, it is noted that the main categories of service sustainability factors are policy, technical, social, institutional, financial, environmental, managerial and climatic categories.

A critical review of the DWS service sustainability factors listed in table 10 shows that factors CF1 to CF20 fall under technical issues, and factors CF21 to CF27 fall under managerial issues. Factors CF28 to CF32 are policy issues while factors CF33 to CF38 fall under environmental issues. Factors CF39 to CF44 are for social issues. Factor CF45 is for financial issues, factors CF46 to CF48 are for institutional issues, and factor CF49 is for climatic issues.

Lastly, factors number CF50 to CF63 cover issues that fall under more than one category. Table 11 is an example of how the DWS service sustainability factors listed in table 10 can be grouped under these categories.

Table 11: Factors that affect or can easily affect sustainability of DWS services in Malawi

Categories with factors listed under them								
Technical	**Managerial**	**Policy**	**Environmental**	**Social**	**Financial**	**Institutional**	**Climatic**	**More than one category**
1. Type of technology 2. Quality of infrastructure 3. Proper handover of new infrastructure 4. Infrastructure that works as required 5. Continuous upgrading of infrastructure e.g. extension of pipe network 6. Preventative maintenance 7. Rate of breakdown of Infrastructure 8. Extent of breakdown of infrastructure 9. Performance of consultants 10. Performance of contractors 11. Capacity to maintain infrastructure 12. Capacity to operate infrastructure 13. Performance of suppliers 14. Availability of alternative water sources 15. Efficiency of using water resources 16. Vandalism of infrastructure 17. Growth of water demand 18. Age of infrastructure 19. Availability/adequacy of supplies e.g. power supply 20. Leaking water supply facilities	1. Rewards to people involved in provision of DWS services 2. Involvement of trained personnel 3. Continued training 4. Involvement of motivated personnel 5. Organisational culture adaptation to a project 6. Human resource management 7. Realistic objectives	1. Supportive legislation/ policies 2. Stability of economic status of users 3. Population growth rate 4. Developmental improvements 5. Equity in distribution of water resources	1. Natural condition of water catchment area 2. Protection of water source/catchment area 3. Quantity of raw water 4. Quality of raw water 5. Perennial source of water 6. Social/economic activities in water catchment area	1. Involvement of appropriate stakeholders 2. User involvement 3. Demand-responsive approach 4. User satisfaction with a service 5. Achievement of benefits by users e.g. health and economic 6. Continued use of supplied water as expected at the design stage	1. Availability/ use of adequate financial resources	1. Management arrangement (type) for water supply system 2. Spare parts supply 3. Maintenance tools supply	1. Climate change impacts	1. Lessons from past projects/ organisational learning 2. Troubleshooting 3. Safety of workers 4. Involvement of senior managers in a project 5. External support 6. Project owner requirements 7. Project sponsor regulations 8. Supervision of subordinates 9. Level of water loss 10. Wasteful usage of water 11. Water demand management 12. Inter-community competitions 13. Political support/interference 14. Realisation of service provider expectations

Source: Author

The weakness of categorising the factors based on the types of aspects that the factors affect is that such categorization only indicates the types of issues that are affected. The actual issues that are affected are not indicated. In addition, the factors under one category do not necessarily affect one issue, rather the factors affect different issues. As such, to address an issue, the factors that fall under different categories but affect that particular issue have to be managed. For example, to manage adequacy of supplied potable water, there would be need to address the issue of infrastructure breakdown which is a technical factor; population growth rate which is a policy factor; and quantity of raw water which is an environmental factor, among others. The fact that the factors to be managed to address an issue come from different categories implies that the current categorisation of the factors do not play any role in the management of the factors. Actually, each factor is managed individually. This has a challenge that management of the factors in isolation is complex. Therefore, as part of this research, an investigation will be conducted to establish a relationship of DWS service sustainability factors whereby the factors collectively affect sustainability of DWS services. Such a relationship will enable management of the factors as interactions.

2.6 RECOMMENDED FACTORS FOR SUSTAINABILITY OF DWS

The researchers and practitioners identified sets of factors, which they believe once managed will lead to sustainable DWS services. The identified factors are referred to by different names such as main factors (Binder, 2008), key factors (McConville and Mihelcic, 2007), and critical factors (Sugden, 2003), among others. The number of these factors varies. For example, Binder (2008) identified 3 factors while WaterAid (2010) identified 13 factors. The researchers and practitioners consider the main, key or critical factors important because:

a. The factors are listed in the best-practice guidelines (McConville and Mihelcic, 2007);
b. The factors are cited frequently in the literature (Lockwood, 2003; WaterAid, 2010);
c. The factors are given more weight than other factors by the authors (Lockwood, 2003);
d. The factors are observed to affect sustainability of water supply facilities (Masduqi et al, 2009);
e. Personal experience of the authors and practitioners suggests that the factors are important (McConville and Mihelcic, 2007; WaterAid, 2010); and
f. The factors are identified and given more weight than other factors by the respondents.

The identified factors are considered important either in their own individual right, or as part of a framework.

2.6.1 Individual factors

The researchers and practitioners recommend that, when managing sustainability of the quality and quantity of drinking water, concentration should be on some of the factors. Given below are examples of such factors for Uganda and Malawi. The examples have been taken from Uganda because this is an African country with the highest sustainability level of DWS services (UNDP-WSP, 2006), and from Malawi because this is the country for this study.

The Uganda Ministry of Water and Environment (2011) recommends that if DWS services in the country are to be sustainable, the following factors have to be managed; functionality of water committees, functionality of hand-pump mechanics, spare parts supply, back-up support, ownership of infrastructure, technology choice, community mobilisation and training, financing, gender balance in committees, and monitoring and reporting.

As for Malawi, the Ministry of Water Development and Irrigation recommends that there should be financial self-sufficiency and decentralised day-to-day management of the DWS systems, if the DWS services are to be sustainable (World Bank, 2007).

2.6.2 Factors in frameworks

Some researchers and practitioners state that it takes more than one factor for sustainability of DWS services to be affected. Such factors appear together in frameworks whose examples include framework for sustainable rural water supply services by WaterAid (2010), sustainability model of rural water supply systems by Masduqi et al, (2009), and sustainability snapshot by Sugden (2003).

2.6.2.1 Framework for sustainable rural water services by WaterAid (2010)

WaterAid (2010) developed a framework for facilitating sustainable rural water supply services as shown in figure 2. WaterAid (2010) states that community-based and externally-supported operation and maintenance (O&M) system for sustainable rural water supply services can be put in place by combining aspects of project design and implementation (factors 2 to 8 in figure 2), and aspects of external support (factors 9 to

13 in figure 2). This framework shows that for DWS services to be sustainable, factors 1 to 13 in figure 2 have to be managed.

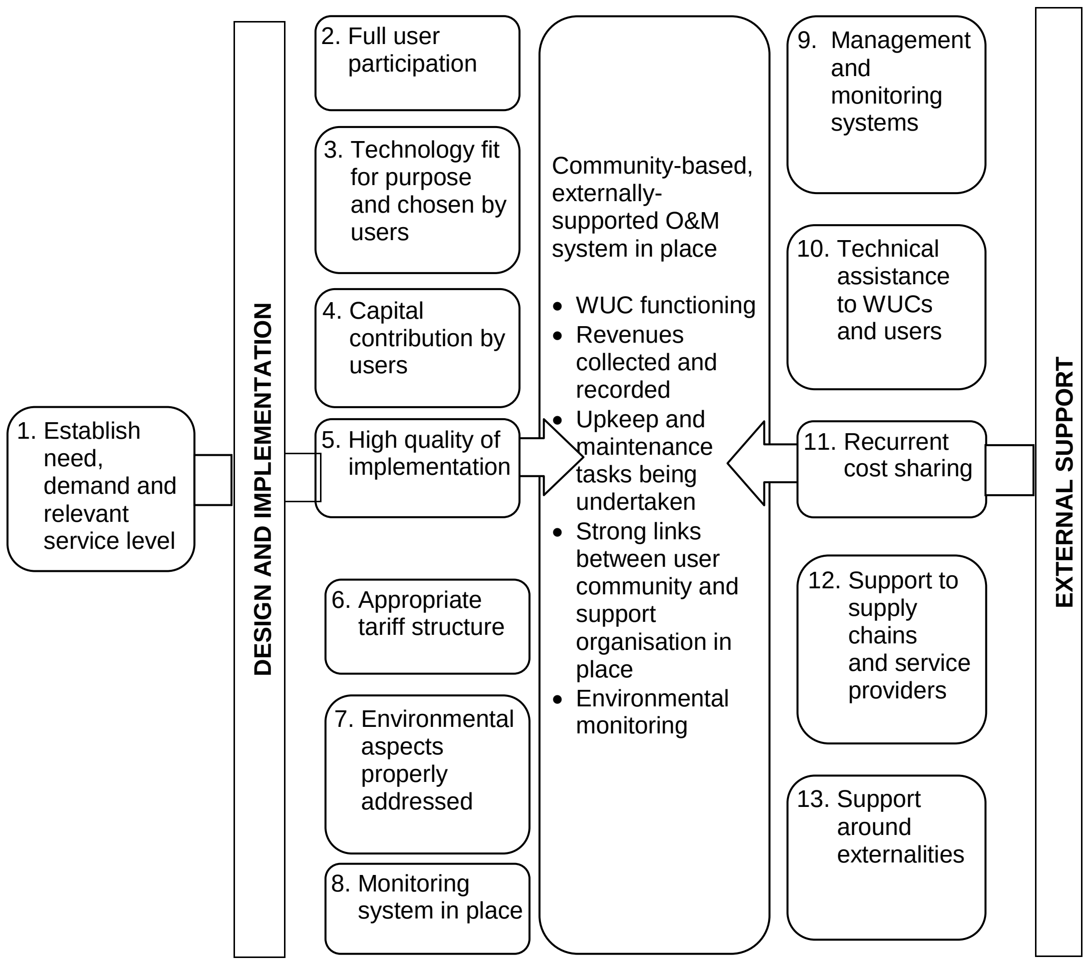


Figure 2: Framework for sustainable rural water supply services

Source: WaterAid (2010)

2.6.2.2 Sustainability model of rural water supply by Masduqi et al (2009)

Masduqi et al (2009) developed a mathematical model which is used to calculate sustainability index before a decision is made to implement a rural water supply project. The required inputs into the model are the data related to the following parameters:

i. Water sources in the local area with sufficient discharge, history of water sources, and whether or not available water is of good quality and is safe to be consumed;
ii. Type of planned water supply technology;
iii. Sources of funds for development of water facilities, and amount of available funds compared to the required funds;

iv. Ease of water facilities operation, possibility of damage occurrence, and ease of repair if there is damage;
v. Institution that will be formed to manage water including institutional training plan;
vi. Local human resources to operate water facilities and/or training plan for local people to operate the facilities;
vii. Ease of getting spare parts for components of the technology used;
viii. Sources of funds for operating facilities, and amount of available funds compared to required funds; and
ix. Form of public participation in planning of the water facilities, technology selection, socialisation, implementation, and operation.

Inclusion of the above parameters in the model shows Masduqi et al (2009)'s belief that if DWS services are to be sustainable, all the above factors have to be managed.

2.6.2.3 Sustainability snapshot by Sugden (2003)

Sugden (2003) developed a framework for evaluating potential sustainability of a project in terms of whether or not the community for which the project is implemented has funds, skills, and spare parts and equipment to carry out repairs. According to this framework, once there are funds, skills, and spare parts and equipment to carry out repairs, DWS services will be sustainable.

2.6.3 Limitations of the factors recommended to be managed

The DWS service sustainability factors discussed in sections 2.6.1 and 2.6.2 are reviewed in this section to check if they could address all the sustainability challenges faced by the DWS systems in Malawi. As presented in section 1.4,

a. Functionality level of water supply systems;
b. Capacity of water supply systems to produce and supply adequate water;
c. Capacity of water supply systems to produce safe water;
d. Quantity of available raw water; and
e. Quality of raw water,

have been identified at this stage of the study as the aspects that affect sustainability of DWS services in Malawi. A comprehensive set of aspects that affect sustainability of DWS services in Malawi will be developed through case studies that will be conducted in this research. Therefore, at this stage, only the aspects mentioned above will be used to check potential effectiveness of the factors perceived to be important (discussed in sections 2.6.1 and 2.6.2) in addressing the sustainability challenges of the DWS services.

Starting with the individual factors that are recommended to be managed for sustainability of DWS services in Uganda (section 2.6.1), and assuming that all the listed factors would be managed, it is noted that functionality of hand-pump mechanics, technology choice, and spare parts supply would ensure that the infrastructure functions continually. However, most of the factors recommended to be managed in Uganda would not specifically address any of the 5 challenges of sustainability of DWS services in Malawi (mentioned above and discussed in section 1.4). Such factors include functionality of water committees, back-up support, ownership of infrastructure, community mobilisation and training, financing, gender balance in committees, and monitoring and reporting.

The above means that the factors recommended to be managed for sustainability of DWS services in Uganda would not be able to address the issues of availability of adequate and good quality raw water, and continued availability of adequate and safe water to the users. It should be noted that only two components of sustainability were assessed in the study which ranked Uganda the highest in Africa in terms of sustaining DWS services. The two components were institutional and financial sustainability (UNDP-WSP, 2006).

As regards the individual factors that have been recommended to be managed for sustainability of DWS services in Malawi (section 2.6.1), and assuming that the two recommended factors (financial self-sufficiency and decentralised day-to-day management of the DWS systems) would be managed, none of the 5 challenges of sustainability of DWS services in Malawi (mentioned above and discussed in section 1.4) would be specifically addressed.

In terms of frameworks, the framework for sustainable rural water supply services by WaterAid (2010) focuses on operation and maintenance of infrastructure, and sources of water as the aspects that affect sustainability of DWS services (section 2.6.2.1). Therefore, if this framework was used in Malawi, it would address issues of functionality level of infrastructure, and quantity and quality of raw water. However, the framework would not be able to address the issue of continued safety and adequacy of water provided to the users. This is the case because while the framework talks of monitoring of compliance of services to the standards, it does not indicate concrete actions that need to be taken, when and by who, in order to address the shortfalls that would be identified during the monitoring.

Similarly, the sustainability model of rural water supply systems by Masduqi et al (2009) has its focus on sustainability potential of water sources, project infrastructure and operational activities of water supply systems. Therefore, if the model was used in Malawi, it would address issues of functionality level of infrastructure, and quantity and quality of raw water. However, as it is the case with the framework for sustainable rural water supply services by WaterAid (2010), the model by Masduqi et al (2009) would not be able to address the issue of continued safety and adequacy of water provided to the users. The framework would not address these issues because they are not covered in the framework.

On its part, the sustainability snapshot by Sugden (2003) only assesses sustainability potential of water infrastructure through maintenance. Therefore, if it was used in Malawi, it would address the issue of functionality level of infrastructure. The framework would not be able to address issues of quantity and quality of raw water as well as continued safety and adequacy of water provided to the users.

It will be noted from the above discussions that the factors discussed in sections 2.6.1 and 2.6.2 would not address all the sustainability issues of DWS services in Malawi. Some sets of the factors would address certain issues, and other sets of the factors would address other issues. This is the case despite that the issues identified at this stage of the study, against which potential effectiveness of the factors has been checked, may not be the only issues that affect sustainability of DWS services in Malawi.

It should also be noted that there is no indication that the factors that are recommended to be managed for sustainability of DWS services in Uganda and Malawi, as well as those outlined in the 3 frameworks discussed above, are based on the interactions of the factors. This implies that the factors that are recommended to be managed are not necessarily based on the interactions of the factors, but are selected based on some of the reasons listed in (a) to (f) in section 2.6. The challenge of not selecting the factors based on their interactions is that the selected factors are not necessarily the root causes as recommended in most problem solving models (Rebori, 1997; Restructuring Associates Incorporation, 2008), and the challenge of not managing the root causes is that sustainability failure of DWS services would continue (Dew, 1991; Doggett, 2005).

The above shows that there is a need to come up with a holistic framework that can be used to manage all the root causes of sustainability failure of DWS services in Malawi.

2.7 NEED FOR A HOLISTIC DWS SERVICE SUSTAINABILITY FRAMEWORK

The limitations in the sets of the factors that are recommended to be managed for sustainability of DWS services (section 2.6.3) raise the need for a holistic DWS service sustainability framework. The new framework should address the limitations of the sets of factors as presented in section 2.6.3. In addition, the new framework should have the following characteristics:

a. Holistic:

As it can be noted from table 10, there are a number of factors that can potentially affect DWS service sustainability. It is necessary that the new framework should manage all these factors. This is supported by Nkambule and Peter (2012) who state that all the possible factors should be considered.

b. Empirical:

The new framework should be developed based on empirical findings. This will ensure that the framework will be capable of solving practical problems.

c. Simple:

The new framework should be simple so that it can easily be understood and used by DWS practitioners. This is necessary if the framework is to be used otherwise practitioners may ignore it. As such, generic strategies and tactics for addressing the factors should be provided. This is important so that the users of the framework should not be required to think from scratch but review the generic strategies and tactics, and select and use the appropriate ones. The users should develop new strategies and tactics only where the generic strategies and tactics are not appropriate for a situation.

d. Implementable by service providers:

The new framework should be designed in such a way that it can be implemented by service providers. As such, other than the required external support, which should be identified and agreed at the time of developing the strategies and tactics for achieving sustainable DWS services, the service providers should be able to provide the requirements and carry out most of the activities recommended in the framework.

2.8 RESEARCH PROPOSITION

The literature as reviewed and discussed in section 2.4 shows that there are a number of factors that can potentially affect DWS service sustainability. The factors are listed in table 10. The researchers state that each of the factors is important for sustainability of DWS services.

Narrowing down to Malawi, it is noted at this stage of the research that sustainability of DWS services is affected by a number of aspects. Such aspects include:

a. Functionality level of water supply infrastructure;
b. Capacity of water supply infrastructure to produce and supply adequate water;
c. Capacity of water supply infrastructure to produce safe water;
d. Quantity of available raw water; and
e. Quality of raw water.

On infrastructure, it is noted that some infrastructure is used beyond its useful life time without being refurbished. As a result, such infrastructure becomes dilapidated. On the quality and quantity of raw water, it is noted that the quantity and quality of raw water for some water supply systems keep on deteriorating and decreasing respectively with passage of time. While this is the case, it is observed that the sets of the factors that are currently recommended to be managed for sustainability of DWS services do not address all aspects required for sustainability of DWS services. Some sets of the factors manage certain aspects while other sets of the factors manage other aspects. In addition, the factors that are recommended to be managed are not necessarily the root causes of the deterioration of DWS services but are selected based on their popularity and perceived order of importance.

Based on the above observations, a proposition is made that:

“DWS services in Malawi can be sustained if all the root causes of sustainability failure of DWS services are identified and managed”

As such, the key question that this research intends to answer *(“Does management of the root causes of sustainability failure of DWS services improve sustainability of DWS services in Malawi?”)* is pertinent to confirm that DWS services in Malawi can be sustained by managing the root causes.

2.9 RESEARCH QUESTIONS

Based on the research objectives outlined in section 1.7, five specific questions have to be answered in order to address the research problem. The five questions are:

Q1. Are the quantities and quality of water supplied to the users in the selected DWS systems in Malawi sustained?

Q2. Which factors affect sustainability of DWS services?

Q3. How do the factors collectively affect sustainability of DWS services?

Q4. Which factors need to be managed for sustainability of DWS services?

Q5. How should the factors be managed in order to sustain DWS services in Malawi?

Questions Q2 and Q4 have been answered in sections 2.4 and 2.6 respectively through literature review. However, to obtain empirical answers based on the situation in Malawi, these questions (Q2 and Q4) as well as questions Q1, Q3 and Q5 are taken forward.

Chapter summary

Chapter 2 has presented a critical review of the literature on sustainability of DWS services. The definition and attributes of DWS service have been presented in the chapter. The chapter has also outlined the factors and frameworks for service sustainability with particular emphasis on DWS services.

Limitations of the sets of the factors that are recommended to be managed for sustainability of DWS services have been identified in the chapter. The limitations show that there is a need to come up with a holistic framework that can be used to facilitate DWS service sustainability, otherwise not all aspects required for DWS service sustainability can be managed.

Lastly, five key questions have been formulated which need to be answered in order to address the research problem for this study.

CHAPTER THREE - RESEARCH METHODOLOGY

Introduction

This chapter outlines the research methodology that was used for this study. The research paradigm, and techniques for data collection and analysis that were used in the research are discussed in this chapter. In addition, the chapter provides the criteria that were used to select the cases. Details of the selected cases as well as the participants in the research are also provided in the chapter.

3.1 RESEARCH PROBLEM, AIM AND QUESTIONS

The research problem for this study is that:

“The quantity and quality of drinking water (DWS services) in Malawi decreases and deteriorates respectively as time passes after commissioning of the water supply systems”

A critical review of the literature showed that there are so many factors that affect sustainability of the quantity and quality of drinking water (DWS services). It was further noted that if all the aspects required for sustainability of DWS services are to be maintained, all the factors have to be managed. However, only a few factors have been highlighted in the literature as being critical for sustainability of DWS services. As such, only those factors are recommended to be managed.

Further observation is that the factors that are recommended to be managed are not necessarily the root causes of the deterioration of the DWS services. This implies that there is a chance that some of the root causes are neither identified nor managed. By not identifying and managing all the root causes, the existing ways of sustaining the DWS services would not be able to maintain all the required aspects for sustainability of the DWS services. Consequently, the quantity and quality of drinking water deteriorate with passage of time in Malawi. Therefore, the aim for this research, viz:

“To identify the root causes of sustainability failure of DWS services in Malawi, evaluate the outcomes of managing the root causes on sustainability of DWS services, and develop a framework for managing the identified root causes” was still pertinent at this stage of the research if the DWS services in Malawi were to be sustained.

In order for the root causes to be identified and a framework to be developed, there was a need to answer the following five research questions:

Q1. Are the quantities and quality of water supplied to the users in the selected DWS systems in Malawi sustained?

Q2. Which factors affect sustainability of DWS services?

Q3. How do the factors collectively affect sustainability of DWS services?

Q4. Which factors need to be managed for sustainability of DWS services?

Q5. How should the factors be managed in order to sustain DWS services in Malawi?

Having defined the research questions, the next step was to select an appropriate research paradigm.

3.2 RESEARCH PARADIGM

A paradigm adopted for this study is critical realism. Critical realism holds that what people experience are sensations, which are simply representations of what is real i.e. reality is stratified (Bhaskar, 1978; Outhwaite, 1987). It is, thus, argued that one can only understand what is going on in the social world (observable events) if he understands the social structures that give rise to the phenomena (unobservable events) (Bhaskar, 1989) i.e. one can only acquire knowledge of the external world by critical reflection on perception and its world.

Critical realism also acknowledges that there is a variety of structures, procedures and processes that interact with one another, and that all these structures, procedures and processes need to be understood if one is to understand what gives rise to a phenomenon (Bhaskar, 1989). This was an important quality for this study in that DWS in Malawi involves a number of structures, procedures and processes. The structures include water users, Water Boards and the Department of Water Supply Services. The procedures include regulations to be followed when procuring services, goods or works, and regulations to be followed when adjusting water tariffs. On the other hand, processes include project appraisal, design, construction, operation, maintenance, and monitoring and evaluation of WSSs that provide DWS services (Gosling, 2010; Griffiths, 2007; Khan, 2000). The factors that affect sustainability of DWS services were, therefore, studied with regard to these structures, procedures and processes in order to understand their impact on sustainability of DWS services in Malawi.

Critical realism also recognises that social structures are at different levels, and as such, there is need for multi-level study. It is argued that findings from each of the levels have the capacity to change the researcher's understanding of that which is being studied (Saunders et al, 2009). This was another relevant quality of critical realism to this study. This is the case in that social structures in DWS in Malawi are at the level of the individual, the group and the organisation. Individual level is where individual water users and individual staff members working for the service providers present their personal views on issues. Group level is where water users and staff members present issues as groups, and organisation level is where staff members working for the service providers articulate issues from their organisations' point of view. Sustainability of DWS services in Malawi was studied at all these levels so that findings from different levels could be triangulated. Individuals presented their personal views and what is stipulated in the organisations' guidelines through descriptive and analytical surveys as well as one-to-one interviews. On the other hand, views were presented by groups through focus group discussions.

As regards research methodology, critical realism rejects choosing of a particular paradigm, instead it advocates selecting research methods and techniques according to the nature of the phenomena under investigation (Fleetwood and Ackroyd, 2004). In order to accommodate all the five (5) research questions for this study, some of which are for determining relationships between one variable and another while others are for exploring phenomena, both quantitative and qualitative methods were used in the research.

The critical realist paradigm is, however, not appropriate for a research aimed at predicting, quantifying and measuring results (Fleetwood and Ackroyd, 2004). This weakness did not apply to this research in that the framework that would be developed was not for predicting, quantifying nor measuring results. The framework would be for providing guidelines that needed to be followed to ensure sustainability of DWS services.

3.3 RESEARCH STRATEGIES

Root cause analysis, survey and multiple case studies were the research strategies that were used in this study. Figure 3 shows an overview of these strategies and the outputs that were expected.

Strategy 1	Root cause analysis (based on factors from the literature)
Output	Causal relationships of the factors that affect sustainability of DWS services as per the experience of the participants to a focus group discussion and descriptions in the literature
Strategy 2	Descriptive survey
Output	Confirmation of applicability in practice in Malawi of the combined effects (from root cause analysis) that affect sustainability of DWS services
Strategy 3	Multiple case studies
Output	Factors that affect sustainability of DWS services in the case WSSs in Malawi
Strategy 4	Analytical survey
Output	Validation of some of the root causes of sustainability failure of DWS services in Malawi
Strategy 5	Root cause analysis (based on the factors that affected sustainability of DWS services in the multiple case studies)
Output	Causal relationships of the factors that affected sustainability of DWS services in the case WSSs as per the explanations of the respondents

Figure 3: Overview of the strategies for this research and expected outputs

Source: Author

As indicated in figure 3, root cause analysis was conducted in the research to establish causal relationships amongst the factors that affect sustainability of DWS services. Two root cause analyses were conducted. The specific objective of the first analysis was to identify the combined effects of the factors. This analysis was done based on the factors from the literature. On the other hand, the specific objective of the second analysis was to identify the root causes of sustainability failure of DWS services in Malawi. This analysis was conducted based on the factors that affected sustainability of DWS services in the case WSSs.

As regards survey, both descriptive and analytical surveys were conducted in the research. The descriptive survey was used, among others, to present the identified combined effects of the factors to the practitioners in DWS management in Malawi. The aim was for the practitioners to confirm if the combined effects identified through the cause-and-effect analysis were applicable in practice in Malawi.

On the other hand, analytical survey was conducted to validate some of the root causes which were identified by constructing the current reality tree. The root causes that were to be validated were those which affect a particular factor together with other root causes. For example, availability of spare parts, availability of maintenance tools, and human resources management are the root causes which affect timeliness of maintaining leaking water supply infrastructure which, after affecting other factors, eventually affect quantity of available raw water. Principal component analyses were conducted for such root causes. The aim of the analyses was to check the level of influence of each of the root causes. The analyses were based on the responses from the analytical survey.

As indicated above, the other strategy that was used in the research is multiple case studies. The researcher found the strategy suitable for the research at hand because of the following strengths of the strategy:

a. Case study approach is used in conditions where several elements and multiple dimensions of a subject need to be studied exhaustively (Alavi and Carlson, 1992; Benbasat, 1987; Eisenhardt, 1989; Yin, 2002). This quality made case study strategy suitable for the research at hand. This was the case in that as noted in table 10, there were a number of factors that needed to be studied under the research.

b. Case study strategy illuminates what decisions were taken, why they were taken, how they were implemented, and with what result (Schramm, 1971). This was a relevant quality to the research at hand. This was so in that research question Q1 (sections 2.9 and 3.1) was for finding out what was done in the case WSSs, why and how were those activities carried out, as well as what results were realised by implementing those activities.

c. Case study strategy is appropriate for answering explanatory questions such as “how” and “why” (Yin, 1994). This was relevant to the research at hand in that two of the five research questions (Q3 and Q5) were explanatory (“how”) questions (sections 2.9 and 3.1).

d. Case study is a viable strategy for conducting research where the enquirer has little control over the events being studied (Yin, 1994). In line with this quality, case study was appropriate for this research in that the researcher had no control on the factors that affected sustainability of DWS services in Malawi.

e. Case study strategy relies on multiple sources of evidence (Creswell, 1998; Yin, 2002). This was a beneficial quality that allowed use of multiple sources of evidence which was useful in triangulating the data.

In spite of having the above strengths, case study strategy has some weaknesses. The major one is that it is not advisable to generalise the findings from a case study (Glesne and Peshkin, 1992; Kennedy, 1976). In order to mitigate this weakness, multiple case study approach was adopted for this study (Lee, 1989; Yin, 1994). Herriot and Firestone (1983) contend that the evidence from multiple cases is more compelling, and the overall study is regarded as being more robust. Dyer and Wilkins (1991), however, argue that multiple case study approach has its own weakness. It is stated that, under multiple case study, researchers pay less attention to the specific context, instead more attention is paid to the ways in which the cases can be contrasted. In the research at hand, this criticism was overcome by studying each case in such a way that there was in-depth understanding of each case.

3.4 RESEARCH DESIGN

The methods that were used to collect and analyse data, as well as the participants from whom the information was collected, are discussed in this section. These aspects are discussed under the selected research strategies as follows:

3.4.1 Root cause analysis

The researcher facilitated two focus group discussions in which two root cause analyses of the factors were conducted. One analysis was for identifying the combined effects of the factors that affect sustainability of DWS services while the other analysis was for identifying the root causes of sustainability failure of DWS services in Malawi. Five participants took part in the analyses. The 5 participants were people who worked at middle management level at Northern Region Water Board. The participants worked on design, implementation, operation, maintenance, and undertook monitoring and evaluation of the DWS systems, which are key activities that affect sustainability of DWS services (Gosling, 2010; Griffiths, 2007; Khan, 2000). The participants had enough relevant experience having worked in DWS management in Malawi for between 5 and 15 years.

The two analyses were conducted based on the experience of the participants as well as the information from the literature (especially works of the authors shown in tables 8 and 9, as well as section 2.4.3) and the case WSSs.

3.4.1.1 Data collection

Two sets of data were collected for the root cause analyses; one set was for identifying the combined effects, and another set for identifying the root causes. The data for identifying the combined effects were the potential factors that could affect sustainability of DWS services listed in table 10. The factors were from the literature based on 43 studies conducted from 1960s to date (2014).

On the other hand, the data for identifying the root causes were the factors that were identified from the multiple case studies. The methods that were used to identify the factors are explained in section 3.4.5.

3.4.1.2 Data analysis

Two methods of the root cause analysis were used in the research, namely; cause-and-effect analysis and construction of a current reality tree. The output from the cause-and-effect analysis was a fish-bone diagram, and the output from construction of the current reality tree was a current reality tree. The fish-bone diagram showed the combined effects of the factors that affected sustainability of DWS services. On the other hand, the current reality tree showed the chains of the cause-and-effect relationships of the factors that affected sustainability of DWS services in Malawi (Dettmer, 1997). The chains showed the combined effects of the factors at one end, and the root causes at the other end.

It was important that the root causes of sustainability challenges should be identified and addressed otherwise symptoms could be addressed, and the challenges would continue to exist (Dew, 1991; Doggett, 2005).

3.4.2 Survey

Both descriptive and analytical surveys were conducted in the research. The descriptive survey was used to present the identified combined effects of the factors to the practitioners in DWS management in Malawi. The purpose was for the practitioners to confirm if the combined effects identified through the root cause analysis were applicable in practice in Malawi. On the other hand, analytical survey was conducted to validate the root causes that affect a particular factor together with other root causes in the interaction that leads to a particular combined effect.

3.4.2.1 Data collection

Structured questionnaires were used to collect data for both descriptive and analytical surveys. Structured questionnaires were used because they are efficient in gathering views from a large number of practitioners (Sun and Meng, 2009).

The respondents for the study were people who worked in organisations that provided DWS services in Malawi. The selected people worked at middle management level, and were involved in design, implementation, operation, maintenance, and undertook monitoring and evaluation of the DWS systems. These are key activities that affect sustainability of DWS services (Gosling, 2010; Griffiths, 2007; Khan, 2000).

People at middle management level were considered to be appropriate respondents for the surveys because they were the ones who either undertook the above activities in person or supervised implementation of the activities directly. As such, these people had adequate knowledge of the management of DWS services in Malawi. Senior managers were left out because they were earmarked for one-to-one interviews at a later stage of the research.

The total number of the possible respondents was 50. Since this number is small, it was decided that data would be collected from all the possible respondents and that all the data would be analysed. A questionnaire was e-mailed to all the 50 possible respondents, and 40 completed questionnaires were returned. This represents 80% response rate, which is much higher than the acceptable minimum range of 30-40% for surveys (Moser and Kalton, 1971). Forty respondents were adequate for this study because the respondents were more than 30, which is the recommended minimum number for the results not to be spurious (Roscoe, 1975; Saunders et al, 2009; Stutely, 2003).

For analytical survey, a questionnaire was e-mailed to the 50 possible respondents, and 30 completed questionnaires were returned. Thirty respondents were adequate in that, with a maximum of three predictor variables, there were more than 5 times as many participants as predictor variables which is the absolute minimum number required for the results to be valid (Brace et al, 2012; Hair et al, 1998).

3.4.2.2 Data analysis

The quantitative data from the structured questionnaires was analysed using computer-based quantitative analysis software, the Statistical Package for the Social Sciences (SPSS). The statistical analyses that were conducted using the package included one-sample t-test statistical analyses and principal component analyses.

3.4.3 Multiple case studies

The subsections that follow discuss; (i) the cases that were studied (ii) data collection techniques (iii) data analysis techniques, and (iv) data analysis protocols, that were used and followed respectively under multiple case studies.

3.4.4 Cases that were studied

Purposive sampling was used to select the cases that were studied. The selected cases satisfied the following requirements:

1. Each case was a piped DWS system in Malawi;
2. Each case WSS had been in operation for at least 10 years;
3. There were at least two case WSSs where the minimum required quantity of water supplied per capita and the quality of water supplied had been sustained over the years, and at least other two case WSSs where the minimum required quantity of water supplied per capita and the quality of water supplied had not been sustained;
4. There were at least two case WSSs from each of the three administrative regions of Malawi (northern, central, and southern);
5. There were at least two case WSSs from each type of the institutions that managed the DWS systems in Malawi (water board and community);
6. There were at least two case WSSs that used water from each of the following four types of water sources; lake, dam, river, and borehole; and
7. There were at least two case WSSs where water supply was by gravity, and at least other two case WSSs where water supply was by pumping.

The above characteristics were used to ensure that the case WSSs were a representative of all types of the piped DWS systems in Malawi.

Based on the above characteristics, ten piped DWS systems were chosen for this study. Ten cases was a good number noting that several researchers state that 2 to 12 cases are optimal (Eisenhardt, 1989; Sekeran, 2000; Yin, 1994). Table 12 gives an overview of the case WSSs, and figure 4 shows the locations of the case WSSs in Malawi.

Table 12: Overview of the case WSSs for the current research

Case No.	Name of piped DWS system	Administrative region in Malawi	Period of operation (years)	Year of last major upgrading and extension works	Type of managing institution	Type of water source	Sustainability of		Means of water supply
							Minimum required quantity of water supplied per capita	Quality of water supplied	
1	Chintheche	North	29	2003	Water Board	Lake	√	√	Pumping
2	Chipoka rural	Central	23	N/A	Community	River	X	X	Gravity
3	Chipoka town	Central	29	N/A	Water Board	Lake	√	√	Pumping
4	Chiradzulu	South	49	N/A	Water Board	River	√	√	Gravity
5	Chitipa	North	46	2003	Water Board	Boreholes	√	√	Pumping
6	Ighembe	North	40	N/A	Community	River	X	X	Gravity
7	Mudi	South	61	1980	Water Board	Dam	√	√	Pumping
8	Mzuzu	North	74	2013	Water Board	Dam	√	√	Pumping
9	Nkhamanga-Lunyina	North	36	N/A	Community	River	X	X	Gravity
10	Salima	Central	39	2003	Water Board	Boreholes	√	√	Pumping

Key: N/A ~ No major upgrading works have been carried out
√ ~ sustained
X ~ not sustained

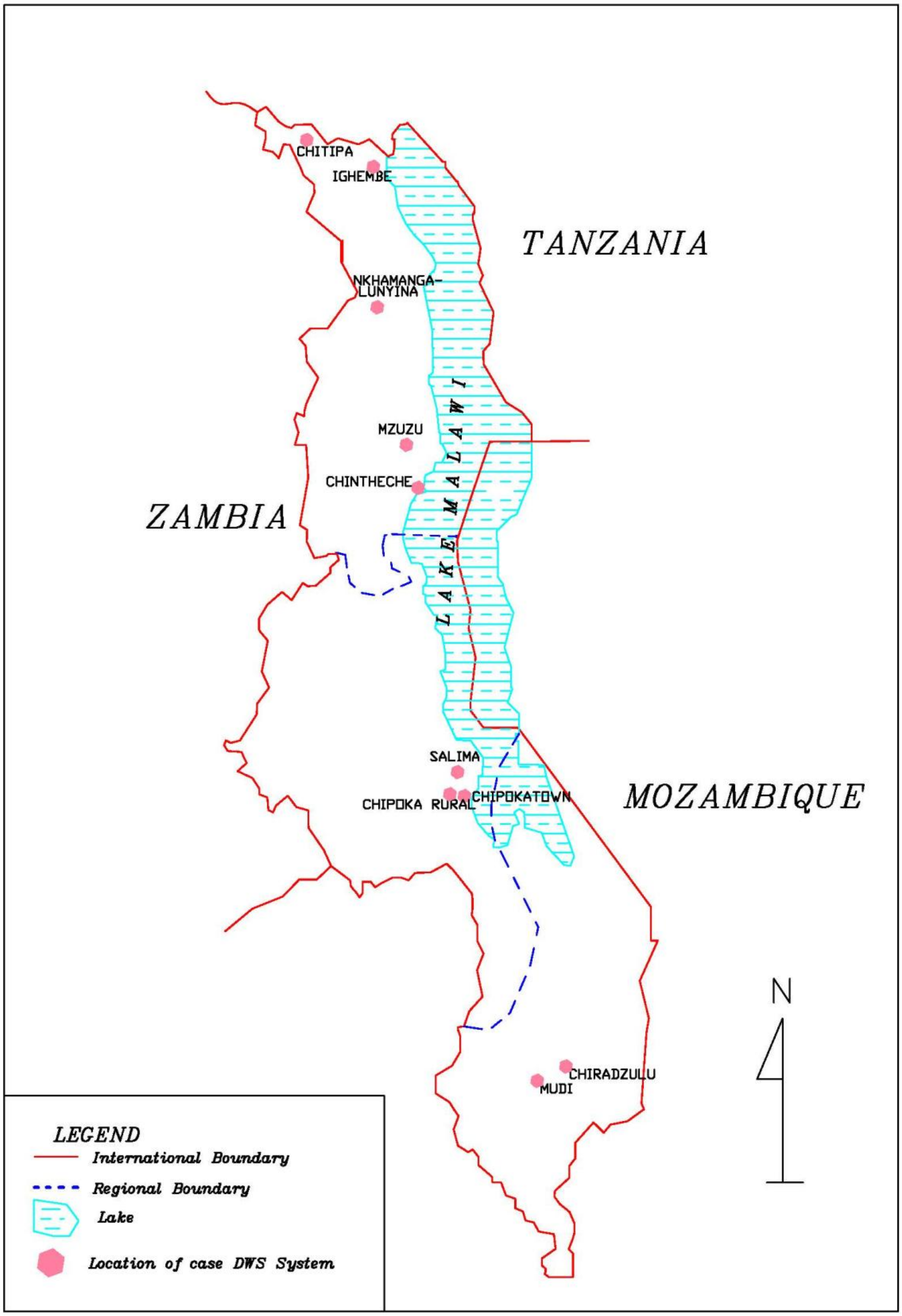


Figure 4: Map of Malawi showing locations of the case DWS systems

The sub-sections that follow describe the case water supply systems selected for this study:

a. Chintheche water supply system

Chinthenche Water Supply System (WSS) provided drinking water to the town of Chintheche in the Northern Region of Malawi. There were two WSSs 5 km apart that supplied water to 2 small village towns in Chintheche. The two WSSs were established in the 1980s, and had a combined total production capacity of $264m^3$/day. In 2003, one of the two WSSs was upgraded and expanded so that it would be able to supply water to the area which was initially served by the other WSS. The WSS which was not upgraded was abandoned. The capacity of the upgraded Chintheche WSS was $800m^3$/day. The source of water was Lake Malawi.

Chintheche WSS was established by the Department of Water Supply but it was being managed by the Northern Region Water Board (NRWB) at the time of this study since 1996. It served 6,450 people in 2005 and the number increased to 6,845 people by 2014. These population figures imply that the available quantity of water per capita per day decreased from 124 litres in 2005 to 117 litres in 2014. Both per capita figures per day were, however, above the minimum of 36 litres per capita per day recommended by the Government of Malawi for piped DWS systems (Malawi Ministry of Irrigation and Water Development, 1994). Water from Chintheche WSS was supplied to the users by pumping. Records showed that water from Chintheche WSS was safe for human consumption.

b. Chipoka rural gravity water supply system

Chipoka rural gravity water supply system (RGWSS) supplied water to the rural areas of Chipoka in the Central Region of Malawi. The WSS was established in 1991 and was being managed by the community at the time of this study. The source of water for Chipoka RGWSS was Mchololo River. The catchment area for Mchololo River was not protected.

The production capacity of Chipoka RGWSS in 1991 was $363m^3$/day. The WSS used to provide water to 6,543 people translating into a per capita supply of 55 litres per day. However, the number of functional taps kept decreasing from a total of 18 in 1991 to 1 in

2012 to the time of the study in 2014. The one tap, with a flow of 9.6m^3/day, provided water to 800 people translating into a per capita supply of 12 litres per day. The rest of the people who used to get water from this WSS, drew water from other sources. The major reason why the system was not functional is that calcium deposits in the water clogged the pipelines. Water from Chipoka RGWSS was supplied to the users by gravity. Records showed that, at the time of the study, water supplied from Chipoka RGWSS was no longer safe for human consumption.

c. Chipoka town water supply system

Chipoka town WSS was established in the 1980s to provide drinking water to the town of Chipoka in the Central Region of Malawi. At the time of this study, the WSS was being managed by Central Region Water Board since 1996.

The source of water for Chipoka town WSS was Lake Malawi and the production capacity was 480m^3/day. The system supplied water to 4,000 people in 1997 and to 4,700 people in 2014. This means that the quantity of water available for supply decreased from 120 litres/capita/day in 1997 to 102 litres/capita/day in 2014. The per capita water supply for both 1997 and 2014 were above the minimum of 36 litres per capita per day recommended by the Government of Malawi for piped DWS systems (Malawi Ministry of Irrigation and Water Development, 1994). Water from Chipoka town WSS was supplied to the users by pumping. Records showed that the water supplied from Chipoka town WSS was safe for human consumption.

d. Chiradzulu water supply system

Chiradzulu WSS served the headquarters of Chiradzulu District in the Southern Region of Malawi. The WSS was established in the 1960s by the Water Supply Department. At the time of this study, Chiradzulu WSS was being managed by Southern Region Water Board since 1996.

The source of water for Chiradzulu WSS was Chisambaadzukulu River which originated from Chiradzulu Mountain. The catchment area for the river was not a protected area.

The capacity of Chiradzulu WSS had been 217m^3/day since its establishment. The WSS served 1,838 people in 1997 and 4,225 people in 2014. As such, the per capita water supply decreased from 118 litres per day in 1997 to 51 litres per day in 2014. The per capita water supply for both 1997 and 2014 were above the minimum of 36 litres per capita per day recommended by the Government of Malawi for piped DWS systems (Malawi Ministry of Irrigation and Water Development, 1994). Water from Chiradzulu WSS was supplied to the users by gravity. Records showed that the water provided by Chiradzulu WSS was safe for human consumption.

e. Chitipa water supply system

Chitipa WSS supplied drinking water to the headquarters of Chitipa District in the Northern Region of Malawi. Chitipa WSS was established in 1968. In 1996, Chitipa WSS was handed over from the Department of Water Supply to Northern Region Water Board which was managing the system at the time of this study.

The source of water for Chitipa WSS were boreholes. The capacity of the WSS in 2003 was $300m^3$/day. The WSS served 4,971 people in 2003 translating into a supply of 60 litres per capita per day. To increase the available water, additional boreholes were drilled such that by 2014, the capacity of the WSS was $658m^3$/day. In 2014, the WSS served 10,986 people which was equivalent to 60 litres per capita per day.

The per capita water supply remained constant at 60 litres per day from 2003 to 2014. This per capita water supply figure was above the minimum recommended quantity of 36 litres per day for piped DWS systems (Malawi Ministry of Irrigation and Water Development, 1994). Water from Chitipa WSS was supplied to the users by pumping. Records showed that water from Chitipa WSS was safe for human consumption.

f. Ighembe rural gravity water supply system

Ighembe WSS was established in 1974. The WSS used to supply drinking water to the rural communities of Ighembe in the Northern Region of Malawi. The capacity of Ighembe WSS was $171m^3$/day since its construction in 1974. The WSS served 2,376 people in 1974, an equivalent of 72 litres per capita per day. The WSS was managed by the community at the time of this study.

The source of water for Ighembe WSS was Kasangwa River. The catchment area for the river was not protected and was actually inhabited. When it was noted that the run-of-river was not adequate to meet the water demand, a decision was made to construct a dam on the same river. Construction of the dam took place from 2008 to 2010. It was, however, noted that the volume of water stored in the dam would not be enough for both irrigation and DWS as intended. As such, the dam was not connected to the DWS system. At the time of this study, alternative raw water sources were being assessed.

Just before the WSS stopped being functional in 2008, Ighembe WSS served 6,490 people translating into a per capita supply of 26 litres per day. The people who used to get water from this WSS before it became non-functional collected water from other sources at the time of this study. Ighembe WSS supplied water to the users by gravity. Records showed that water supplied from Ighembe WSS at the time it became non-functional was no longer safe for human consumption.

g. Mudi water supply system

Mudi WSS was established in 1953 to supply drinking water to the communities who lived where Blantyre City is located in the Southern Region of Malawi. The source of water for Mudi WSS was Mudi Dam which was on Mudi River. The catchment area for Mudi River was not protected. Mudi WSS was being managed by Blantyre Water Board at the time of this study.

The capacity of Mudi WSS was 45,000m^3/day in 1980 after implementation of upgrading works. Mudi WSS served 160,200 people that time translating into a per capita water supply of 281 litres per day. However, due to siltation of the dam and inefficiency of pumping equipment, the capacity of Mudi WSS decreased to 4,000m^3/day by 2014. The system served 70,000 people in 2014 from part of Blantyre City (the other part of the City was served by another WSS) which translates into a per capita supply of 57 litres per day. The per capita water supply for both 1980 and 2014 were above the minimum of 36 litres per capita per day recommended by the Government of Malawi for piped DWS systems (Malawi Ministry of Irrigation and Water Development, 1994). Water from Mudi WSS was supplied to the users by pumping. Records showed that water from Mudi WSS was safe for human consumption.

h. Mzuzu water supply system

Mzuzu WSS was established in the 1940s to provide drinking water to the communities who lived where Mzuzu City is located in the Northern Region of Malawi. Mzuzu WSS was being managed by Northern Region Water Board at the time of this study in 2014.

The source of water for Mzuzu WSS was Lunyangwa Dam which was on Lunyangwa River. Both Lunyangwa River and Lunyangwa Dam were in Kaning'ina Forest Reserve, which was a protected area.

The capacity of Mzuzu WSS used to be 13,660m^3/day from 1993, but increased to 21,200m^3/day in 2010 after implementation of upgrading works. The WSS served 74,593 people in 2005 translating into 183 litres per capita per day, and 115,680 people in 2014 translating into 183 litres per capita per day. The per capita water supply remained constant at 183 litres per day from 2005 to 2014. This per capita water supply figure was above the minimum recommended quantity of 36 litres per day for piped DWS systems (Malawi Ministry of Irrigation and Water Development, 1994). Water from Mzuzu WSS was supplied to the users by pumping. Records showed that water from Mzuzu WSS was safe for human consumption.

i. Nkhamanga-Lunyina rural gravity water supply system

Nkhamanga-Lunyina rural gravity WSS was established in 1978 to provide drinking water to the rural areas of Nkhamanga in the Northern Region of Malawi. The source of water for Nkhamanga-Lunyina WSS was Lunyina River. The catchment area for Lunyina River was the protected Nyika National Park. Nkhamanga-Lunyina RGWSS was being managed by the community at the time of this study.

The capacity of Nkhamanga-Lunyina WSS remained 798m^3/day since its establishment in 1978. The WSS served 11,527 people in 1978 and 32,436 people in 2014. This implies that the per capita water supply decreased from 69 litres per day in 1978 to 25 litres per day in 2014. The 2014 per capita per day water supply was lower than the minimum of 36 litres per capita per day recommended by the Government of Malawi for piped DWS systems (Malawi Ministry of Irrigation and Water Development, 1994). Water from Nkhamanga-Lunyina WSS was supplied to the users by gravity. Records showed that, at the time of this study, water supplied from Nkhamanga-Lunyina RGWSS was no longer safe for human consumption.

j. Salima water supply system

Salima WSS was established in the 1970s to provide drinking water to Salima Town which is in the Central Region of Malawi. Salima WSS was being managed by Central Region Water Board at the time of this study.

The source of water for Salima WSS were boreholes. The capacity of the WSS in 2003 was 2,676m^3/day. The WSS served 20,460 people in 2003 and 27,500 people in 2014. This means that the per capita water supply for Salima WSS was 131 litres per day in 2003 and 97 litres per day in 2014. The per capita water supply for both 2003 and 2014 were above the minimum of 36 litres per capita per day recommended by the Government of Malawi for piped DWS systems (Malawi Ministry of Irrigation and Water Development, 1994). Water from Salima WSS was supplied to the users by pumping. Records showed that the water provided by Salima WSS was safe for human consumption.

3.4.5 Data collection

Interviews, focus group discussions, document analysis, and observation were used to collect data from the case WSSs. Use of various data collection techniques is acceptable in case studies (Yin, 1994). This was important in that employment of various techniques to collect data reduces the chance of misinterpreting the data (Stake, 2000). This is known as data triangulation, which is the combination of methodologies in the study of the same phenomenon (Denzin, 1970).

The major method that was used to collect data from the case WSSs was interviews. This was the case, because as noted by Silverman (1985), interview data display realities, which are neither biased nor accurate, but simply real. A semi-structured interview instrument, based on the literature review and the results from the descriptive survey, was used.

In order to get a comprehensive and varied account of the key issues in the case WSSs, at least three senior managers were interviewed from each of the five institutions that managed the case WSSs. A total of 17 respondents were interviewed. The five institutions (participating organisations) were the Department of Water Supply Services, Blantyre Water Board, Central Region Water Board, Northern Region Water Board and Southern Region Water Board. Considering their positions, educational qualifications, work experience, and professional background, the senior managers were considered to have adequate knowledge of DWS management in their organisations (Saqib et al, 2008). The senior managers were requested to provide insight of the performance of the DWS systems as well as details of the projects that they implemented to resolve the challenges.

In addition to interviewing the senior managers, focus group discussions were held as a second method of collecting data from the case WSSs. Focus group discussions were held with some of the water users in each of the 10 case WSSs. The water users who took part in the discussions were those who accepted the request to do so by the Scheme Managers of the case WSSs. The numbers of the water users who participated in the focus group discussions ranged from 6 to 10. These numbers were just right because they were within the recommended range of 4 to 12 participants (Saunders et al, 2009). The discussions were facilitated by the researcher who requested the water users to indicate their level of satisfaction with the provided water supply services especially the quantity and quality of water supplied.

All interviews and focus group discussions were recorded with prior permission of the respondents. The recordings were transcribed immediately after the interviews and focus group discussions. This enabled timely studying of the collected information to improve the data collection process (Crawford et al, 2004; Silverman, 2005). The following systematic data review protocols were observed to enhance the data collection process for the research at hand:

a. Interviews and focus group discussions were transcribed and reviewed before the next round of interviews and focus group discussions. Missing information was noted;
b. The collected data which was not clear was verified with the respondents for accuracy;
c. The semi-structured questionnaire was enhanced before the next round of interviews and focus group discussions to take into account the gaps in the collected data. The semi-structured questionnaire was also enhanced to ensure that similar data would be collected from all the cases for easy comparison of the cases; and
d. The above three steps were repeated until all the relevant data was collected.

The third method that was used to collect data from the case WSSs was document analysis. Various documents including performance quarterly and annual reports were studied rigorously.

The last method that was used to collect data was observation. Water sources and infrastructure for the case WSSs were observed by the researcher in order to take note of the issues that affected sustainability of DWS services. This is supported by Sara and Katz (1998) who state that factors for sustainability of DWS services can be identified through examination of the systems.

3.4.6 Data analysis techniques

The qualitative data that was collected from the case WSSs was analysed using one of the grounded theory data analysis methods, thematic analysis. Thematic analysis method was used because of its systematicity and transparency in data analysis. This is the case because the approach uses a structured process (Guest et al, 2011).

Thematic analysis, being one of the grounded theory data analysis methods, was appropriate for this study in that it is an approach that can be used at the data analysis stage irrespective of the data collection approach employed (Creswell, 1998; Hussey and Hussey, 1997; Myers, 1997; Strauss and Corbin, 1998). This was a beneficial characteristic for this study in that, as indicated in section 3.4.5, various methods were used to collect data from the case WSSs.

Since the qualitative data (from the one-to-one interviews and focus group discussions) was mainly on the combined effects of the factors, which had been identified from the cause-and-effect analysis conducted as part of the research, the thematic analysis was driven by these combined effects i.e. the thematic analysis was analytic (theoretical) and not inductive (Braun and Clarke, 2006). In addition, since the intention was to find out the real causes of sustainability failure of DWS services in Malawi, the thematic analysis was latent utilising the semantic content of the data.

The following process, which consisted of three stages, namely; open coding, selective coding, and development of thematic structure, were used to analyse the data.

a. Open coding

Open coding is a process of developing categories from the collected data (Flick, 2006). The data was broken into incidents, ideas, events, and actions through which concepts were discovered. Once discovered, the concepts were grouped together into categories based on their similarities. Then sub-categories were identified based on the established categories. The sub-categories were the when, where, why, and how sustainability failure of DWS services occur (LaRossa, 2005). It was an 'open' process in that the data was explored without making any reference to the themes established in the preceding stages of the research.

b. Selective Coding

Selective coding is a process of refining and integrating the categories to form themes (Flick, 2006). Based on the categories identified in (a), themes for each case WSS were generated. Two conditions needed to be satisfied for a category to be identified as a theme. One, a theme was supposed to be central i.e. many categories should have related to it. Two, a theme was supposed to appear frequently in the data i.e. there should have been indicators in all the case WSSs that pointed to the theme (LaRossa, 2005). In this research, the factors that affected sustainability of the DWS services were the categories while the combined effects of the factors were the themes.

c. Development of a thematic structure

Based on the findings in (a) and (b) above, a thematic structure showing how sustainability failure of DWS was caused in each case WSS was developed. The structure also showed what needed to be done for the DWS services to be sustainable.

The thematic structure consisted of the following specific parameters, as suggested by Flick (2006) based on the paradigm by Strauss (1987):

i. Conditions

This was the data which showed what led to the DWS services to be unsustainable, and why this was the case.

ii. Interaction amongst the actors

This was the data on the factors that affected sustainability of DWS services, and how the factors interacted to affect sustainability of DWS services.

iii. Strategies and tactics

This was the data on how the factors should be managed for DWS services to be sustainable.

iv. Consequences

This was the data on the expected results after implementation of the strategies and tactics in (iii).

The thematic structures for the different case WSSs were analysed. Comparison was made amongst the structures, and in the end one thematic structure was developed which showed a general picture of the situation in all the case WSSs.

It should be noted that the developed thematic structure is contained in the current reality tree (figure 6) and the framework developed for sustainable DWS services in Malawi (figure 14).

3.4.7 Data analysis protocols

A thorough review of interview records and a series of post-interview communications were carried out with the respondents to ensure that the data was accurate.

In addition, a number of researchers in social sciences recommend use of triangulation techniques at the data analysis stage to improve the validity and reliability of the research findings (Denzin, 1970; Jick, 1979; Miles and Huberman, 1984). Hussey and Hussey (1997) state that use of different approaches, methods, and techniques in the same study overcome potential bias and sterility. Therefore, data triangulation was employed to improve the accuracy, reliability, and validity of the findings. The interview data of a case was verified and evaluated by constant comparison with the data collected from other sources within the case WSSs.

A factor was considered valid during data analysis if it satisfied the following four qualifying criteria:

1. Each factor was mentioned and supported by two or more respondents;
2. Each factor played a significant role in the sustainability (or un-sustainability) of DWS services in one or more DWS systems under one or more participating institutions;
3. Respondents provided instances of how a particular factor influenced the sustainability of the DWS services in their respective organizations; and

4. The interview data supporting each factor was verified with data from other sources within the concerned DWS system.

3.5 RESEARCH ETHICS

There is need to consider various ethical issues while conducting research (Bryman, 2004; Christians, 2000; Hussey and Hussey, 1997). For the research at hand, the following ethical issues were considered:

1. Obtaining informed consent from the participating organisations as well as the respondents. Further consent was obtained from the respondents before recording them during interviews and/or focus group discussions;
2. Safeguarding the privacy, confidentiality and anonymity of the participating organisations as well as the respondents; and
3. Ensuring accuracy of the data before publishing the research findings.

In order to consider ethical issues as outlined above, the following ethical protocols were observed:

1. While descriptions of the case WSSs were provided, the particulars of the case WSSs were separated from the analytical arguments and conclusions;
2. The particulars of the respondents were separated from the analysis and conclusions;
3. Data accuracy was ensured at various stages of this study using triangulation;
4. Consent of the organizations and respondents was obtained, wherever necessary, before publishing the work based on this research study; and
5. The empirical materials were safeguarded during and after this research project, to protect the privacy of the respondents and the organizations involved in the study.

Chapter summary

Chapter 3 has provided research methodology for the study. Based on their characteristics and qualities, critical realism was chosen as the most appropriate research paradigm, root cause analysis, survey and multiple case studies as the most appropriate research strategies, and fish-bone diagram, current reality tree, SPSS and thematic analysis as the most appropriate data analysis methods.

CHAPTER FOUR - RESEARCH FINDINGS

Introduction

This chapter presents the findings of this research, and the framework which has been developed to facilitate sustainability of DWS services in Malawi. The findings are based on the results from the descriptive survey, one-to-one interviews, focus group discussions as well as analytical survey. The findings are presented in six sections. The first section discusses sustainability of the quantity and quality of water supplied in the case WSSs. The second section presents the combined effects of the interactions of the factors that affect sustainability of DWS services in Malawi. The third section is where, based on the interactions of the factors, the root causes of sustainability failure of the DWS services are identified. The strategies and tactics for ensuring sustainability of DWS services in Malawi are also proposed in this section. The fourth section discusses the requirements which are critical for effective implementation of the proposed strategies and tactics. Based on the above findings, a sustainability framework for DWS services in Malawi has been developed and is presented in the fifth section. Finally, the sixth section provides guidance on the best way of using the developed framework to sustain DWS services in Malawi.

4.1 SUSTAINABILITY OF DWS SERVICES IN THE CASE WSSs

Section 3.4.4 presented a discussion on the total quantity of water available for supply per capita in each of the 10 case WSSs in Malawi. The section also presented a discussion on the quality of water produced and supplied by each case WSS. On the other hand, the discussion in this section is on the quantity and quality of water actually used by the consumers in the case WSSs. The discussion of the quantity and quality of water actually used by the consumers is supported by Montgomery et al (2009) who state that, to determine the benefits from supplied water, it is the use which should be measured.

The findings on the quantity and quality of water used by the consumers in the case WSSs are based on the data which was collected from one-to-one interviews, focus group discussions, and from the results of the tests which were conducted to check availability of residual chlorine in the stored water. Except for residual chlorine tests which are described in section 4.1.2, the rest of the methods have been described in chapter 3. The results from the analyses are as follows:

4.1.1 Quantities of water used by the consumers

The quantities of water that the users who participated in the focus group discussions drew from the case WSSs are shown in table 13.

Table 13: Quantities of water that users drew from the case WSSs

Case water supply system No.*	**Average quantity of water drawn for each member in the household for the focus group participant No.** (litres/capita/day)										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Average**
1	50	78	47	40	52	67	-	-	-	-	56
2	52	78	41	48	122	61	73	75	47	33	63
3	70	119	70	56	40	80	-	-	-	-	73
4	67	144	87	53	95	72	-	-	-	-	86
5	233	156	39	67	50	72	106	39	117	42	92
6	71	39	39	100	63	58	200	72	40	78	76
7	133	92	87	54	304	180	133	95	-	-	135
Overall average											83

Note:

* These numbers are used to distinguish one case WSS from another and not to identify the systems. Quantities included in the table are for 7 case WSSs because water drawn from the other 3 case WSSs was not measured.

When analysed, information in table 13 shows that the average quantity of water that the participants in the focus group discussions drew from the case WSSs was 83 litres/capita/day. During the focus group discussions, most of the water users stated that they topped up the water drawn from the case WSSs with water from other sources. This shows that the users found the quantities of water that they collected from the case WSSs not adequate. This is not surprising as WSP (2009) states that having access to improved water supply does not mean getting adequate services.

The users considered the quantities of water drawn from the case WSSs not adequate despite that the quantities were far more than the minimum of 36 litres per capita per day recommended by the Government of Malawi for piped DWS systems (Malawi Ministry of Irrigation and Water Development, 1994). Actually, 98% of the participants drew more than 36 litres/capita/day. This shows that the recommended minimum amount is less than the quantities that would be adequate for the users in the case WSSs.

The reasons why the users drew less water from the case WSSs than what would be adequate for them are given in box 1.

Box 1: Reasons why the users drew less water from the case WSSs

> “We are forced to use unsafe water because either there is water supply interruption or we want to control water bills” (Respondent No. 26a)
>
> “This is the case because water supply is available only for 3 hours per day from 2am” (Respondent No. 23d)
>
> “These days water supply is available twice per week and we only draw 2 pails of water at a time” (Respondent No. 27c)
>
> “We only use water from the service provider for drinking, cooking and bathing. We do not use the water for other activities like gardening for fear of high bills” (Respondent No. 23a)
>
> “Since we have other things that we need to pay for, we have a limit on how much from our earnings should be paid towards water” (Respondent No. 23d)
>
> “To make sure that the water bill does not shoot beyond what I can afford, I wash clothes once in a week, on Saturdays only” (Respondent No. 23c)
>
> “We control the amount of water that we use for fear of cost. Water is expensive” (Respondent No. 26b)
>
> “In order to avoid high bills, the water from the service provider is used for drinking, cooking and bathing only. Washing of clothes and utensils is done at the lakeshore using lake water” (Respondent No. 26c)
>
> “We know that borehole and lake water is not safe for human consumption because it does not undergo treatment process. However, we still use this water as a way of controlling water bills” (Respondent No. 26d)

The quotations in box 1 show that the users drew less water from the case WSSs because of two reasons;

a. There was insufficient water flow to meet the users’ needs; and
b. The water users did not have enough money to pay for adequate water.

This finding is consistent with the observation by Howard and Bartram (2003) that the quantities of water drawn by the users depend on accessibility, reliability and potential cost of the water.

Inadequate supply of water, however, creates challenges. The participants in the focus group discussions encountered the challenges shown in box 2 as a result of inadequate water supply.

Box 2: Challenges encountered because of inadequate water supply

> "When the stored water is used up, we drink the water collected from the boreholes and wells" (Respondent No. 27a)
>
> "With the scarcity of water here, and how expensive it is, when a rat dies in a container with water, all we do is fish out the rat, and use the water for washing the utensils, mopping floors and bathing" (Respondent No. 27b)
>
> "We keep water from the boreholes and wells for flushing the toilets. In some cases, people use pit latrines at the neighbour's homes" (Respondent No. 27c)
>
> "About 75% of the people who work here stay in the nearby City. Water supply challenges are a contributing factor apart from scarcity of houses. Actually, some people have refused to stay here even if a house is identified because of water supply challenges" (Respondent No. 27d)

While the observation that, where potable water is not adequate, people are forced to use water from unsafe sources is well-documented (Carter et al, 1999; Harvey and Reed, 2006), the following from box 2 have not yet been widely documented, if documented at all:

a. People who have flush toilets only, and no pit latrines at their homes are forced to use pit latrines at their neighbours' homes; and
b. People are forced to stay in a nearby town and commute to work a distance of about 20km to run away from water supply problems at their workplace town.

As regards topping up inadequate water that the users drew from the case WSSs, it was noted that additional water was fetched from other sources. The sources from which additional water was fetched included wells, hand-pump boreholes, rivers, and the lake. However, there were a number of challenges that were encountered when drawing water from those other sources as per the quotations in box 3 from the water users.

Box 3: Challenges encountered when drawing water from other sources

> "We travel long distances to find water when there are water supply interruptions" (Respondent No. 23a)
>
> "We have to find money to pay for water from other sources, which is unplanned

expenditure” (Respondent No. 23b)

“We spend greater part of the nights at a well where we queue for water. When you go there at 7pm, your turn to draw water may come around 3 or 4am” (Respondent No. 27a)

“Fights erupt at boreholes and wells where people want to be first to draw water” (Respondent No. 27b)

“Those of us who are employed hire people to collect water for us. They charge MK100 (US$0.29) per pail of water. In my case, I use 8 pails of water per day translating into MK800 (US$2.32) per day on top of monthly bills from the service provider” (Respondent No. 27c)

“When the situation gets very bad, we travel a distance of 7km whose fare is MK150 (US$0.43) to wash clothes at a dam” (Respondent No. 27d)

“Housemaids quit jobs to run away from the burden of fetching water” (Respondent No. 27e)

“While queuing for water, people sneak out to meet girl/boyfriends. This results in a lot of pre- and extra-marital pregnancies. This may also contribute to spread of HIV/AIDS. In addition, this affects marriage life as wives leave homes around 8pm only to come back at 4am” (Respondent No. 27f)

“People go to work without taking a bath” (Respondent No. 27a)

“We travel by buses or ride a bicycle for a distance of 7km to fetch water” (Respondent No. 27b)

“Performance of work at the offices by ladies goes down because they come to work late and tired” (Respondent No. 27d)

“There is only one borehole where we collect water for free. Because the water is free, there is a lot of people queuing for water such that when you go there at 3am, you only come back at 6am” (Respondent No. 32c)

“Since we use flush toilets, we are forced to bring some water in pails from the boreholes to be put in the cisterns for flushing the toilets” (Respondent No. 26a)

“There are long queues at the borehole because the borehole serves about 700 people during water supply interruptions” (Respondent No. 26b)

“We abandon other work to fetch water” (Respondent No. 26c)

“The alternative water that we use is unsafe for human consumption” (Respondent No. 26d)

“Since there are long queues, water from boreholes is collected at awkward hours like 9pm or 4am. Wives leave their husbands in beds thereby affecting their marriage life, and sometimes it leads to mistrust between husbands and wives” (Respondent No. 26e)

“Children go to school late because they have to fetch water first” (Respondent No. 26f)

“Hygiene is affected because activities like washing of clothes are suspended” (Respondent No. 26a)

> “People who have water connections at their homes are considered as being of high status in a society. The moment water supply stops and those people fetch water from the boreholes, their status is affected” (Respondent No. 26c)
>
> “Since the water supply is not reliable, we also make monthly contributions of MK100 to the people who manage the boreholes otherwise we would not be allowed to draw water from the boreholes. This is also the case because we get top-up water from the boreholes to avoid high bills” (Respondent No. 26d)
>
> “When the boreholes break down, people come to collect water from our houses because they argue that we also collect water from the boreholes when there is water supply interruptions” (Respondent No. 26b)
>
> “We keep water from the boreholes and wells for flushing the toilets. In some cases, people use pit latrines at the neighbour’s homes” (Respondent No. 27a)

Box 3 shows that people faced a number of challenges when fetching water from sources other than water points of the piped water supply systems. While most of the challenges are well-documented (section 1.1), the following have not yet been widely documented, if documented at all:

1. Some people pay a lot of money (probably more than they pay for potable water) to draw water from unsafe sources e.g. US$0.29 per 20 litre pail;
2. Some people spend up to two-thirds of the night (8pm to 4am) waiting for their turn to draw water;
3. Fights erupt in the course of competing to be the first one to draw water;
4. Some people travel as long as 7km searching for water to wash clothes;
5. Queuing for water for a long time away from guardians/spouses leads to increased cases of pre- and extra-material affairs as people have a lot of time idling. This results in early or unwanted pregnancies. Those affected either drop out of schools or their marriages break up. This may also lead to spread of HIV/AIDS; and
6. Marriage life is affected in that a spouse spends most of the night fetching water leaving the partner in bed at home. Mistrust may develop between the spouses.

4.1.2 Quality of water used by the consumers

Water drawn from the 10 case WSSs was not always safe for human consumption. One reason for this is that, in some of the case WSSs, the water was no longer treated to the level where it was safe for human consumption. This was the case in 3 of the 10 case WSSs as indicated in section 3.4.4.

For the case WSSs which produced and supplied safe water, sometimes the water was used after it had lost its safety. This was the case because of prolonged storage of the water. Most of the water users who participated in the focus group discussions had at some point stored some water to be used in the times of water supply interruptions. The frequency and period of the water supply interruptions were as shown in box 4.

Box 4: Quotations showing the frequency and period of water supply interruptions

"Water supply interruptions in our area can take as long as 3 days" (Respondent No. 23a)

"At the time I was leaving home this morning, water supply had stopped. It may start some time during the day, or it may not start until tomorrow. In such circumstances, we get water from boreholes or rivers…." (Respondent No. 23b)

"While most of the times water interruptions end within hours, sometimes it can take as long as 7 days for the interruptions to end" (Respondent No. 23c"

"... water supply is available only for 3 hours per day from 2am..." (Respondent No. 23d"

"If we do not draw water around 2/3am at night, then we will not draw water that day because by 5am water flow stops for the whole day" (Respondent No. 28a)

"These days water supply is available twice per week and we only draw 2 pails of water at a time" (Respondent No. 27b)

"Before 4 months ago, we could stay for one week without water supply" (Respondent No. 32c)

"While most of the time, water supply interruptions last for hours only, there was a time when it lasted for as long as one month" (Respondent No. 26e)

"Where I live, water has not been flowing for a month now" (Respondent No. 28b)

The quotations in box 4 show that in some areas water supply interruptions occurred every day ("*...water supply is available only for 3 hours per day...."*). In addition, the quotations in box 4 show that it was not uncommon for water supply interruptions to last for 7 days. At times, water supply interruptions lasted for a month.

To ensure that they had water throughout the period of water supply interruptions, most participants in the focus group discussions stored water for a period ranging from 5 to 14 days. The quotations substantiating the period that water was stored are in box 5.

Box 5: Substantiating the period that water was stored by the users in the case WSSs

> "We store water to be used during water supply interruptions. Such water is sometimes stored for as long as 5 days before being used" (Respondent No. 23a)
>
> "We store water for as long as 2 weeks" (Respondent No. 27d)

Whether or not the stored water was safe for human consumption was checked, in terms of availability of residual chlorine. The water was collected from consumer taps, and tested every day for availability of residual chlorine. The tests stopped on the day that it was noted that there was no residual chlorine in the water. The tests were conducted by the Scheme Managers of the case WSSs or the staff members whom they delegated. The results are in table 14.

Table 14: Residual chlorine in the stored water from the case WSSs

Age of stored water (days)	**Content of residual chlorine (mg/100ml) in stored water from the case water supply system No.***						
	1	**2**	**3**	**4**	**5**	**6**	**Average**
1	0.5	0.5	0.8	1.5	0.5	2.5	1.1
2	0.5	0.4	0.6	0.2	0.3	0.6	0.4
3	0.4	0.2	0.4	0	0.1	0.3	0.2
4	0.4	0.1	0.2	0	0	0	0.1
5	0.2	0.1	0.1	0	0	0	0.1
6	0.2	0	0	0	0	0	0
7	0.1	0	0	0	0	0	0
8	0	0	0	0	0	0	0

Note:

* These numbers are used to distinguish one case WSS from another and not to identify the systems. Availability of residual chlorine was checked in the water from 6 case WSSs because chlorine was not applied to the water from 3 case WSSs, and the 10th WSS was not supplying water at the time of the test as its source had dried up.

Table 14 shows that in one of the case WSSs, chlorine remained in the water for as long as 7 days while in another case WSS, chlorine remained in the water for only 2 days. On average, chlorine remained in the water for 5 days. The reduction of the content of residual chlorine with passage of time is supported by Morita-Lou and Waters (2008) who state that the quality of water deteriorates during storage. It should be noted that water which does not contain residual chlorine can easily get contaminated, even by simply handling it without observing hygiene practices (Respondent No. 21). This is the case because chlorine, which protects the water from contamination (Thompson, 2010), would not be available in the water.

While table 14 shows that the water which was stored for more than 5 days did not contain residual chlorine on average, hence could easily get contaminated, the quotations in box 5 indicate that some participants in the focus group discussions used water which had been stored for a period ranging from 5 to 14 days. This means that people who consumed the water which had been stored for more than 5 days were at a risk of contracting waterborne diseases (Calow et al, 2010; WHO, 1993), as the water did not contain any residual chlorine.

Furthermore, when the stored water was used up, and/or when the water drawn from the piped DWS systems was not adequate (section 4.1.1), water collected from unsafe sources was used. Quotations in box 6 substantiate this finding.

Box 6: Quotations on use of water collected from unsafe sources

"The alternative water that we use is unsafe for human consumption" (Respondent No. 26d)

"We use unsafe water from the rivers and wells" (Respondent No. 23e)

"The students at our college draw water from boreholes for their personal use and sometimes for the college kitchen" (Respondent No. 23c)

"The little water we draw from the tap is used for drinking. The water for cooking, bathing and washing is drawn from the boreholes and wells" (Respondent No. 27b)

"During water supply interruptions, we collect water from boreholes and wells" (Respondent No. 27f) "... The water from the borehole is used for drinking while for the rest of the activities we use water from the wells" (Respondent No. 32b)

"Most of us do not apply any disinfectants to the water we collect from the boreholes and wells" (Respondent No. 27c)

It should be noted that water collected from unsafe sources might already be contaminated or can easily get contaminated and cause waterborne diseases to people who consume it (Calow et al, 2010; Carter et al, 1999; WHO, 1993).

From the discussions in this section (section 4.1), it is noted that some people served by the case WSSs used water from unsafe sources because of 3 reasons, namely:

a. Some of the case WSSs no longer produced water which was safe for human consumption;

b. Quantities of water provided by some of the case WSSs did not satisfy the demand of all the users all the time; hence the users topped up the potable water with unsafe water; and
c. Some of the water users collected inadequate water from the case WSSs because they were not able to pay for the required quantities of water. Instead, they topped up the inadequate potable water with water from unsafe sources.

As regards waterborne diseases, it is noted that some people served by the case WSSs suffered from waterborne diseases. The prevalence rates of waterborne diseases in 2011 in the areas served by the case WSSs were as shown in table 15.

Table 15: Prevalence rates of water borne diseases in the case WSSs in 2011

Case WSS No.*	Prevalence rate (%)
1	3.3
2	1.0
3	2.1
4	2.2
5	1.0
6	1.2
7	3.7
8	2.7
Average	2.2

Note:

* These numbers are used to distinguish one case WSS from another and not to identify the systems. The information provided is for 8 case WSSs because there were no health facilities that could be directly related to 2 case WSSs

Source: Malawi Ministry of Health, 2011

Using the finding of the worldwide study by Pruss-Ustun et al (2008), that waterborne diseases where all the people living in an area use unsafe water account for an average of 3.5% of all illnesses, the percentage of the people living in the case WSSs who sometimes used unsafe water has been estimated by interpolation. It is approximated that about 60% of the people in the case WSSs sometimes used unsafe water and consequently suffered from water borne diseases.

4.2 COMBINED EFFECTS OF DWS SERVICE SUSTAINABILITY FACTORS

Section 4.1 shows that apart from affordability challenges (which also affected sustainability of DWS services as it will be illustrated in section 4.3.7), consumers used water from unsafe sources because DWS services from the case WSSs were not sustainable. Literature review conducted in this study and presented in section 2.4 shows that there are 63 factors that affect sustainability of DWS services, which are many. Noting that the factors are not categorised based on their interactions (section 2.5), which presents a challenge on where to start from to address sustainability failure of DWS services holistically, a cause-and-effect analysis was conducted as described in chapter 3. The analysis led to the drawing of a fish-bone diagram for unsustainable DWS services as shown in figure 5.

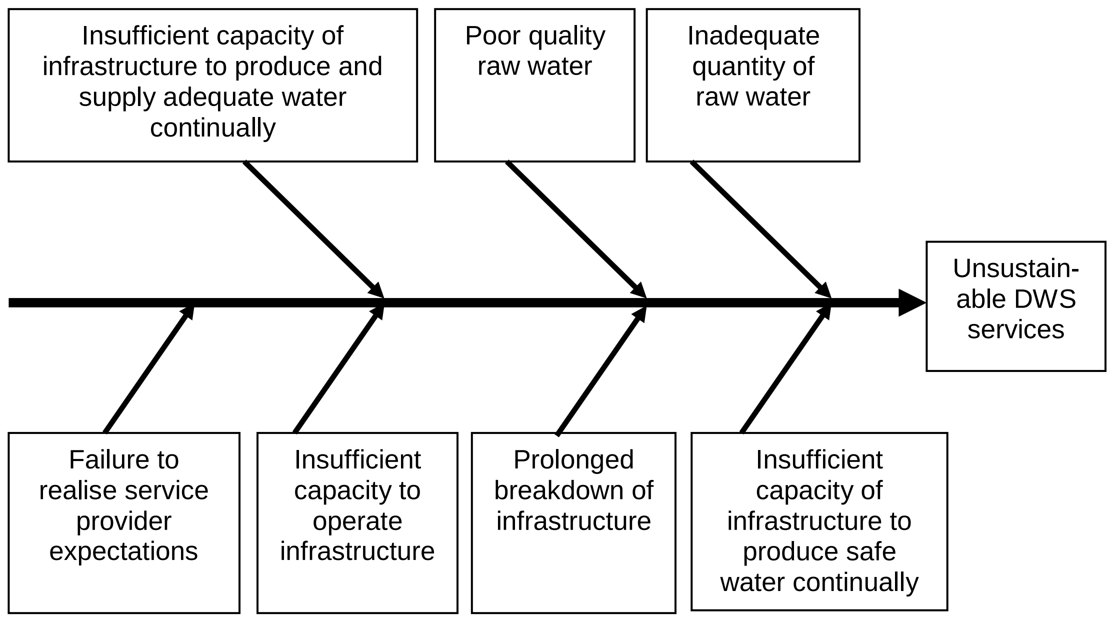


Figure 5: Fish-bone diagram for unsustainable DWS services

Based on the causal categories of the unsustainable DWS services shown in figure 5, it is established that the combined effects of the factors that affect sustainability of DWS services are:

- CE1 - Quantity of available raw water;
- CE2 - Quality of available raw water;
- CE3 - Capacity of infrastructure to produce and supply adequate water continually;
- CE4 - Capacity of infrastructure to produce safe water continually;
- CE5 - Continuity of infrastructure to function as required at the design stage;
- CE6 - Capacity to operate the infrastructure; and
- CE7 - Realisation of service provider expectations.

Since the cause-and-effect analysis, that identified the 7 combined effects of the factors, was based on the experience of only five participants and the information from the literature, applicability of the 7 combined effects in practice in Malawi had to be checked. Views of a bigger number of respondents had to be considered for the findings from the cause-and-effect analysis to be validated. The applicability of the combined effects was checked at two levels; country level, and the level of the 10 case WSSs for this study.

4.2.1 Combined effects at country level

A descriptive survey was conducted to, among other things, find out whether or not the combined effects of the factors, as identified from the cause-and-effect analysis, were applicable in practice in Malawi. Details of the descriptive survey are in chapter 3.

The respondents were asked *"What aspects of your piped DWS systems should be maintained for the DWS services to be sustainable?"* A list of the 7 combined effects was provided. The respondents were supposed to tick the combined effects that were important for sustainability of DWS services in their piped DWS systems.

The respondents ticked different combinations of the 7 combined effects as the aspects that needed to be maintained for sustainability of DWS services in their water supply systems in Malawi. Overall, each of the 7 combined effects was ticked. This validates the finding construed from the results of the cause-and-effect analysis that there are 7 combined effects of the factors that affect sustainability of DWS services. The percentages of the respondents who ticked each combined effect are shown in table 16.

Table 16: % of respondents who identified the 7 combined effects as important

Combined effect	Percentage of respondents
Adequacy of raw water	98
Quality of raw water	85
Continuity of infrastructure to functions as required	85
Capacity of infrastructure to produce and supply adequate water	83
Capacity of infrastructure to produce safe water	78
Capacity to operate infrastructure	78
Realisation of service provider expectations	60

Table 16 indicates that some combined effects of the factors affected sustainability of DWS services in almost all the piped DWS systems where the respondents worked, while other combined effects affected sustainability of DWS services in only some of the piped DWS systems where the respondents worked. To check whether or not the differences in the proportions of the piped DWS systems affected by each of the 7 combined effects (based on the percentages of the respondents who identified the combined effects) were statistically significant, a one-sample t-test statistical analysis was conducted. The results of the analysis are in table 17.

Table 17: Results of one-sample t-test on WSSs affected by the 7 combined effects

One-Sample Statistics

WSSs affected by	N	Mean	Std. Deviation	Std. Error Mean
Quantity of raw water	40	0.98	0.158	0.025
Quality of raw water	39	0.87	0.339	0.054
Infrastructure capacity to produce adequate water	40	0.83	0.385	0.061
Infrastructure capacity to produce safe water	40	0.78	0.423	0.067
Infrastructure functioning as required	40	0.85	0.362	0.057
Capacity to operate infrastructure	40	0.78	0.423	0.067
Realising service provider expectations	40	0.60	0.496	0.078

One-Sample Test

WSSs affected by	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Quantity of raw water	39.000	39	0.000	0.975	0.92	1.03
Quality of raw water	16.075	38	0.000	0.872	0.76	0.98
Infrastructure capacity to produce adequate water	13.559	39	0.000	0.825	0.70	0.95
Infrastructure capacity to produce safe water	11.590	39	0.000	0.775	0.64	0.91
Infrastructure functioning as required	14.866	39	0.000	0.850	0.73	0.97
Capacity to operate infrastructure	11.590	39	0.000	0.775	0.64	0.91
Realising service provider expectations	7.649	39	0.000	0.600	0.44	0.76

Table 17 shows that the differences in the proportions of WSSs in Malawi affected by each of the 7 combined effects were statistically significant. The significant differences imply that some of the 7 combined effects were widespread while other combined effects were not.

The other issue which was investigated was the extent of influence of the 7 combined effects. The respondents were requested to rate the extent of influence of each of the 7 combined effects on sustainability of DWS services in Malawi. The rating was done on a scale of 0 to 5, where 0 is no influence and 5 is maximum influence. For each combined effect, total scores from 40 respondents were calculated against each score point (i.e. 0, 1, 2, 3, 4 and 5), and the results are presented in tables 18 and 19.

Table 18: Total scores on 7 combined effects facilitating sustainability of DWS in Malawi

Combined effect	Total scores against each score point					
	0	1	2	3	4	5
Adequacy of raw water	0	1	0	0	28	150
Quality of raw water	0	1	2	21	32	110
Continuity of infrastructure to functions as required	0	1	6	3	52	100
Capacity of infrastructure to produce and supply adequate water	0	0	0	9	60	95
Capacity of infrastructure to produce safe water	0	0	2	18	44	105
Capacity to operate infrastructure	0	0	12	21	20	90
Realisation of service provider expectations	0	1	10	30	32	75

Table 19: Total scores on 7 combined effects impeding sustainability of DWS in Malawi

Combined effect	Total scores against each score point					
	0	1	2	3	4	5
Adequacy of raw water	0	0	2	9	12	130
Quality of raw water	0	4	0	21	40	60
Continuity of infrastructure to functions as required	0	2	6	15	20	95
Capacity of infrastructure to produce and supply adequate water	0	3	2	6	28	75
Capacity of infrastructure to produce safe water	0	0	6	21	32	75
Capacity to operate infrastructure	0	5	8	9	16	60
Realisation of service provider expectations	0	3	8	30	20	45

Using the total scores in tables 18 and 19, two one-way analyses of variance (ANOVA) were conducted, one where the combined effects were considered to be facilitating sustainability of DWS services in Malawi, and the other where the combined effects were considered to be impeding sustainability of DWS services in Malawi. Tables 20 and 21 show the results of the analyses.

Table 20: Results of ANOVA on how combined effects facilitated sustainability of DWS

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Adequacy of raw water	6	179	29.8	3589.0
Quality of raw water	6	166	27.7	1795.5
Continuity of infrastructure to functions as required	6	162	27.0	1675.2
Capacity of infrastructure to produce and supply adequate water	6	164	27.3	1644.7
Capacity of infrastructure to produce safe water	6	169	28.2	1705.8
Capacity to operate infrastructure	6	143	23.8	1135.4
Realisation of service provider expectations	6	148	24.7	799.9

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	152.3	6	25.4	0.014	1.000	2.372
Within Groups	61726.5	35	1763.6			
Total	61878.8	41				

Table 21: Results of ANOVA on how combined effects impeded sustainability of DWS

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Adequacy of raw water	6	153	25.5	2645.5
Quality of raw water	6	125	20.8	610.6
Continuity of infrastructure to functions as required	6	138	23.0	1303.2
Capacity of infrastructure to produce and supply adequate water	6	114	19.0	858.4
Capacity of infrastructure to produce safe water	6	134	22.3	826.7
Capacity to operate infrastructure	6	98	16.3	485.1
Realisation of service provider expectations	6	106	17.7	305.1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	373.0	6	62.2	0.062	0.999	2.372
Within Groups	35172.3	35	1004.9			
Total	35545.3	41				

The results in tables 20 and 21 show that the level of influence of the combined effects of the factors, on sustainability of DWS services in Malawi, was not statistically different. This means that statistically the combined effects had the same level of influence on sustainability of DWS services in Malawi. This finding implies that there were no trivial combined effects amongst the seven combined effects. Each combined effect was as important as the other combined effects in influencing sustainability of DWS services in Malawi.

The other finding is that by rating the influence of the combined effects above zero (on a scale of 0 to 5) on both how the combined effects facilitated and impeded sustainability of DWS services in Malawi (tables 18 and 19), the respondents showed that the 7 combined effects could either facilitate or impede sustainability of DWS services in Malawi. This supports the observation made by Lim and Muhammad (1999) that factors can either facilitate or impede project success. This implies that each combined effect has to be considered from two perspectives i.e. facilitating and impeding perspectives. This is important in that while a combined effect can facilitate sustainability of DWS services in one water supply system, the same combined effect can impede sustainability of DWS services in another water supply system depending on the state of the combined effect. For example, adequate quantity of available raw water would facilitate sustainability of treated water while inadequate quantity of available raw water would impede sustainability of treated water.

4.2.2 Combined effects in the case WSSs

The applicability in Malawi of the 7 combined effects was also checked at the level of the 10 case WSSs. The data for investigating the applicability of the combined effects in the case WSSs was collected through one-to-one interviews. The details of the one-to-one interviews are provided in chapter 3.

The results from the analysis of the one-to-one interviews show that sustainability of DWS services in the case WSSs was directly affected by the following combined effects:

1. Quantity of available raw water

Quantity of available raw water is one of the combined effects which affected sustainability of DWS services in 4 of the 10 case WSSs. The quotations in box 7 from the interviewees substantiate this finding:

Box 7: Substantiating *'Quantity of available raw water'* as affecting DWS services

> "Quantity of water produced in this water supply system is not adequate because the available raw water is not adequate" (Respondent No. 12-6)
>
> "During dry season, we do not produce water because raw water is not available at all" (Respondent No. 13-5)
>
> "Quantity of available raw water is not adequate for this water supply system hence we need to develop another water source" (Respondent No. 3-8)
>
> "Available quantity of raw water will no longer be adequate once the distribution pipelines are upgraded and people have access to the quantities of water that they need" (Respondent No. 12-8)
>
> "Unsustainable water supply systems can be converted to sustainable water supply systems by simply changing the source of water from those which are not perennial to the perennial water sources. This has worked in one of our water supply systems where water supply has improved for the past three years" (Respondent No. 9-12)
>
> "We supply adequate water during the rainy season because the stream from which we abstract raw water is full of water" (Respondent No. 9-5)
>
> "The situation with water supply systems under our organisation is that where raw water is adequate, treated water is plenty; where raw water is in short supply, treated water is not adequate" (Respondent No. 8-11)

The quotations in box 7 show that the quantity of available raw water affected sustainability of the quantity of treated water produced in some of the case WSSs. Whenever the quantity of available raw water dropped below a certain level, the amount of treated water produced was less than the demand. This is in line with the observation made by Hodgkin (1994) and Morita-Lou and Waters (2008) that the water resources should be sustained if DWS services are to be maintained.

2. Quality of available raw water

Quality of available raw water affected sustainability of DWS services in 4 of the 10 case WSSs. Box 8 contains quotations from the interviewees which substantiate this finding.

Box 8: Substantiating *'Quality of available raw water'* as affecting DWS services

> "When quality of raw water gets bad during floods in the rainy season, the treatment plant fails to handle the poor quality raw water, and the plant is stopped thereby affecting the quantity of water produced" (Respondent No. 8-12)
>
> "The quality of raw water has deteriorated to the extent that the current infrastructure is not able to produce water that meets the required specification. As such, we are planning to

install a pressure filter disused at another water supply system" (Respondent No. 13-5)

It is noted from the quotations in box 8 that the quality of available raw water affected sustainability of both the quantity and quality of treated water produced in some of the case WSSs. This was the case, in terms of the quantity of treated water, because whenever the quality of raw water deteriorated beyond a level which could be treated by the existing infrastructure, the plant was stopped until the quality of raw water improved. Due to stopping of the plant, the quantity of treated water produced was less than what would be produced if the plant was not stopped.

As regards the quality of treated water, whenever the quality of raw water deteriorated beyond a level that was assumed at the time of designing the infrastructure, the quality of treated water was poorer than that produced when the raw water was of a quality equal to or better than that assumed at the time of designing the infrastructure.

The above finding is in line with the observation by Morita-Lou and Waters (2008) that the quality of raw water should be good if the DWS services are to be sustainable.

3. Capacity of infrastructure to produce & supply adequate water continually

Capacity of infrastructure to produce and supply adequate water continually is one of the combined effects which affected sustainability of DWS services in 4 of the 10 case WSSs. The quotations in box 9 from the one-to-one interviews substantiate this finding.

Box 9: Substantiating *'Capacity of infrastructure to produce & supply adequate water'*

"…the water production and supply infrastructure did not have enough capacity to treat all the water from the dam despite that water demand was higher than the quantity that was produced" (Respondent No. 3-8)

"There is intermittent water supply to some areas under this water supply system. However, this problem will no longer be there once the project for upgrading distribution pipe network currently underway is completed" (Respondent No. 12-8)

"Water produced from this water supply system is not adequate for the demand because of lack of investment. Investment has not been made in line with the growth of demand. The same old infrastructure is made to produce water for the ever increasing demand for water" (Respondent No. 8-8)

"The water demand is 30,000m^3/day while this water supply system is able to produce 8,000m^3/day only. The system cannot produce more because there has not been any investment for upgrading the infrastructure" (Respondent No. 1-1)

The quotations in box 9 indicate that the capacity of infrastructure to produce and supply adequate water continually affected sustainability of the quantity of treated water produced and supplied in some of the case WSSs. This was the case because the infrastructure did not have enough capacity to produce and supply adequate water for the demand although it was in good working condition.

4. Capacity of infrastructure to produce safe water continually

The other combined effect that affected sustainability of DWS services in 3 of the 10 case WSSs is the capacity of infrastructure to produce safe water continually. This is evident from the quotations in box 10.

Box 10: Substantiating *'Capacity of infrastructure to produce safe water'*

> "The quality of raw water has deteriorated to the extent that the current infrastructure is not able to produce water that meets the required specification. As such, we are planning to install a pressure filter disused at another water supply system" (Respondent No. 13-5)
>
> "When quality of raw water gets bad during floods in the rainy season, the treatment plant fails to handle the poor quality raw water, and the plant is stopped ..." (Respondent No. 8-12)

The quotations in box 10 show that the capacity of infrastructure to produce safe water continually affected sustainability of the quality and quantity of treated water produced in some of the case WSSs. This was the case because although it was in good working condition, the infrastructure did not have capacity to produce safe water from the available raw water. Consequently, where the infrastructure was forced to continue producing water despite the infrastructure having insufficient capacity to treat the available poor quality raw water, the produced water was of poor quality. Where the plant was stopped because the available raw water was of poor quality which could not be treated using the existing infrastructure, the quantity of water produced was less than what would be produced if the plant was not stopped.

5. Continuity of infrastructure to function as required at the design stage

Continuity of infrastructure to function as required at the design stage is one of the combined effects that affected sustainability of DWS services in 3 of the 10 case WSSs. The quotations in box 11 substantiate this finding.

Box 11: Substantiating *'Continuity of infrastructure to function as required'*

> "There is adequate water supply, and we have had a smooth ride in this water supply system…because the infrastructure is in good working condition" (Respondent No. 3-2)
>
> "…. we are not able to renew the water supply infrastructure. As such, the infrastructure is run down within 3 to 5 years thereby affecting supply of water" (Respondent No. 11-10)

The quotations in box 11 show that continuity of infrastructure to function as required at the design stage affected sustainability of DWS services. Both the quantity and quality of treated water produced were affected. This was the case because the infrastructure which had broken down either partially or in full was not able to produce water which was enough for the demand or safe for human consumption.

6. Capacity to operate the infrastructure

Capacity to operate the infrastructure is another combined effect which affected sustainability of DWS services in 5 of the 10 case WSSs. This is illustrated by the quotations in box 12.

Box 12: Substantiating *'Capacity to operate the infrastructure'*

> "… power supply is erratic; making it impossible to pump water from the boreholes even though water might be available in the boreholes. As a result, days could pass without water supply" (Respondent No. 3-6)
>
> "We are not able to provide continuous water supply because power supply is erratic … Power supply is available for 8 hours per day on average" (Respondent No. 12-6)
>
> "The only issue that affects quantity of water supplied in this area is intermittent power supply" (Respondent No. 12-2)
>
> "Water demand is not met in this water supply system because of frequent power outages… We do not provide water for 24 hours per day ... On average, the water is supplied for 18 hours per day." (Respondent No. 11-10)
>
> "We are failing to provide continuous water supply because we cannot afford power supply. In the last 6 months, ESCOM has disconnected power supply to our water supply facilities

twice because we failed to settle electricity bills" (Respondent No. 6-1)

"Since generators provided power to few boreholes, the pumped water was not enough for everyone" (Respondent No. 3-6)

"I remember one incident whereby we had run out of chemicals and we had to close the water treatment plant until we received the chemicals" (Respondent No. 11-12)

"Plant operators sometimes do not do certain activities like carrying out water quality tests. They attribute this to tiredness since they work for 12 hours at a time. They work for 12 hours because they would not be enough if they were to work for shorter periods" (Respondent No. 12-8)

It is noted from the quotations in box 12 that the capacity to operate the infrastructure affected sustainability of the quantity and quality of treated water produced in some of the case WSSs. The capacity that affected sustainability of DWS services in the case WSSs, as mentioned in box 12, was power supply, availability of water purification chemicals and the number of staff members. Inadequate power supply as well as unavailability of water purification chemicals resulted in production of inadequate quantity of treated water, while inadequate number of staff members resulted in production of water of substandard quality as not all the required tests were conducted.

7. Realisation of service provider expectations

Realisation of service provider expectations is one of the combined effects that affected sustainability of DWS services in one of the 10 case WSSs. Quotations in box 13 illustrate this.

Box 13: Substantiating *'Realisation of service provider expectations'*

"Water supply has not been adequate in this water supply system for the past 14 years... From what I know, there is no project for the time being aimed at addressing issues of water supply problems in this water supply system… As management, we are caught up in a situation where if we had money, do we invest in an area where it is very clear that the invested money will not be recovered...? Or you invest in an area where you are sure to recover your costs? From a business point of view, the priority level of this water supply system is very low" (Respondent No. 9-5)

"Since the customer base is small, the projects that we have been considering to resolve water supply challenges in this water supply system are those that would not require a lot of money such as boreholes" (Respondent No. 9-5) "…but the yields from the boreholes are not adequate" (Respondent No. 13-5)

"Construction of a dam would be too expensive for the water demand in the supply area" (Respondent No. 13-5).

"From my own analysis, … the main challenge for this water supply system is small customer base" (Respondent No. 9-5)

The quotations in box 13 show that realisation of service provider expectations affected sustainability of the quantity of treated water produced in one of the case WSSs. Because senior managers strongly felt that there would be no returns from investments that could be made in the case WSS, no meaningful investment had been made in that particular system in the last 14 years, and there were no plans for any project in the near future. This was the case despite that the amount of treated water produced was not enough for the demand due to inadequate available raw water. Actually, all what the senior managers wanted, in the words of one respondent was that "*The water supply system should be handed over to the neighbouring water supply institution ... We made this suggestion to the Government about 2 years ago"* (Respondent 13-5).

It will be noted from the above discussion that all the 7 combined effects of the factors, identified from the cause-and-effect analysis and validated through the descriptive survey, affected sustainability of DWS services in the case WSSs in Malawi. This confirms the results from the descriptive survey (section 4.2.1) that the 7 combined effects are applicable in practice in Malawi. While each of the seven combined effects had already been identified by the researchers as factors that affect sustainability of DWS services (Abrams, 1998; Al-Tmeemy et al, 2011; Carter et al,1999; Lockwood, 2003), this study has established that these factors are actually a result of interactions of a number of factors. The study has further established that all the factors that affect sustainability of DWS services in Malawi, do so by triggering these seven combined effects.

The benefit of having identified the 7 combined effects is that they will form a much simpler starting point for identifying and managing the root causes of DWS service sustainability failure (as discussed in section 4.3), as opposed to when the 63 factors identified in section 2.4.4 are scattered all over.

4.2.3 Combined effects that affected individual case WSSs

Different combinations of the 7 combined effects of the factors affected sustainability of DWS services in the case WSSs as shown in table 22.

Table 22: Combined effects affecting individual case WSSs

Case water supply system No.*	**Combined effect No.****						
	1	**2**	**3**	**4**	**5**	**6**	**7**
1	√	√	√	√	√	X	X
2	√	X	X	X	X	√	X
3	X	X	√	X	X	X	X
4	X	X	X	X	X	√	X
5	X	X	X	X	X	√	X
6	X	X	X	X	√	√	X
7	X	√	X	√	√	X	X
8	√	√	√	X	X	√	X
9	√	X	X	X	X	X	√
10	X	√	√	√	X	X	X

Key: √ ~ The combined effect affected sustainability of DWS services in the case WSS

X~ The combined effect did not affect sustainability of DWS services in the case WSS

Note:

* These numbers are used to distinguish one case WSS from another and not to identify the systems

** Combined effect No.1 denotes quantity of available raw water;
2 denotes quality of available raw water;
3 denotes capacity of infrastructure to produce and supply adequate water continually;
4 denotes capacity of infrastructure to produce safe water continually;
5 denotes continuity of infrastructure to function as required at the design stage;
6 denotes capacity to operate the infrastructure; and
7 denotes realisation of service provider expectations.

Table 22 shows that each of the 10 case WSSs was negatively affected by at least one of the combined effects. This shows that not all the factors that affected sustainability of DWS services in Malawi were managed as required in each case WSS. Consequently, some aspects required for sustainability of DWS services were not maintained.

The individual case WSSs were affected by the following numbers of the combined effects:

- 3 case WSSs were each affected by 1 combined effect;
- 3 case WSSs were each affected by 2 combined effects;
- 2 case WSSs were each affected by 3 combined effects;
- 1 case WSS was affected by 4 combined effects; and
- 1 case WSS was affected by 5 combined effects.

In discussing sustainability of DWS services in the case WSSs, senior managers with whom one-to-one interviews were held, and water users who participated in the focus group discussions, considered the WSSs, which later turned out to be affected by only one combined effect, to have DWS services which were almost sustainable. Quotations in box 14 substantiate this finding.

Box 14: Substantiating 'WSSs affected by one combined effect are almost sustainable'

> "There is adequate water supply and we have had a smooth ride in this water supply system" (Respondent No. 3-2)
>
> "Water supply is always available except when there is power outage" (Respondent No. 32d)
>
> "Water supply interruptions are rare except when they are carrying out maintenance works" (Respondent No. 24c)
>
> "There is always adequate water supply these days compared to last year" (Respondent No. 30a)
>
> "Water supply is not a major problem here. I think there was good anticipation of future use of the water" (Respondent No. 30b)

On the other hand, the WSS affected by the most number of the combined effects (5 in total) was in a very bad state to the extent that it was not functional.

The above discussion shows that the bigger the number of the combined effects which are in the unfavourable state for sustainability of DWS services, the more adversely affected is sustainability of DWS services in the affected WSS. This is the case where the severity of the unfavourable state of the combined effects is mild. Where the unfavourable state of the combined effects is severe, any one combined effect is enough to cause a WSS not to provide sustainable DWS services. Box 15 contains quotations which substantiate this with regards to some of the combined effects.

Box 15: Substantiating 'One combined effect can lead to unsustainable DWS services'

> "During dry season, we do not produce water because raw water is not available at all" (Respondent No. 13-5)
>
> "I remember one incident whereby we had run out of chemicals and we had to close the water treatment plant until we received the chemicals" (Respondent No. 11-12)
>
> "… power supply is erratic; making it impossible to pump water from the boreholes even

though water might be available in the boreholes. As a result, days could pass without water supply" (Respondent No. 3-6)

"When quality of raw water gets bad during floods in the rainy season, the treatment plant fails to handle the poor quality raw water, and the plant is stopped thereby affecting the quantity of water produced" (Respondent No. 8-12)

As regards which combined effects affected most case WSSs, table 22 shows that out of the 10 case WSSs:

a. Quantity of available raw water affected sustainability of DWS services in 4 case WSSs;
b. Quality of available raw water affected sustainability of DWS services in 4 case WSSs;
c. Capacity of infrastructure to produce and supply adequate water continually affected sustainability of DWS services in 4 case WSSs;
d. Capacity of infrastructure to produce safe water continually affected sustainability of DWS services in 3 case WSSs;
e. Continuity of infrastructure to function as required at the design stage affected sustainability of DWS services in 3 case WSSs;
f. Capacity to operate the infrastructure affected sustainability of DWS services in 5 case WSSs; and
g. Realisation of service provider expectations affected sustainability of DWS services in 1 case WSS.

The 7 combined effects are listed below starting with the one which affected the most number of the case WSSs:

1. Capacity to operate the infrastructure;
2. Quantity of available raw water;
3. Quality of available raw water;
4. Capacity of infrastructure to produce and supply adequate water continually;
5. Capacity of infrastructure to produce safe water continually;
6. Continuity of infrastructure to function as required at design stage; and
7. Realisation of service provider expectations.

The observation that some combined effects affected more case WSSs than the other combined effects did confirms the finding from the descriptive survey (section 4.2.1) that some causes of DWS service sustainability failure were widespread while other causes were not. However, the fact that some combined effects affected more WSSs than other combined effects does not mean that some combined effects are more important than others. As noted in section 4.2.1, all the combined effects have the same level of influence on sustainability of DWS services.

Table 22 further shows that none of the 7 combined effects affected all the case WSSs. The reasons why some of the case WSSs were not affected by some of the combined effects were investigated. The results of the investigation led to the development of the strategies for ensuring that the 7 combined effects should not negatively affect sustainability of DWS services in the piped DWS systems in Malawi. The details are in section 4.3.

4.3 FACTORS, ROOT CAUSES AND STRATEGIES FOR COMBINED EFFECTS

The discussions in section 4.1 have shown that the quantities of water that some of the case WSSs provided to the users were less than the required quantities, and the water provided by some of the case WSSs was not safe for human consumption. While this was the situation at the time of this study, the concerned case WSSs provided adequate and safe drinking water at the time of commissioning the WSSs. This was in line with the requirement of the Ministry of Water Development and Irrigation in Malawi that a WSS can only be commissioned if it supplies adequate and safe water (Respondents No. 15 and 17). This shows that the unsustainable DWS services at the time of the research was a result of the decrease and deterioration of the quantity and quality of drinking water respectively with passage of time.

The factors that affected sustainability of DWS services in the case WSSs are discussed in sections 4.3.1 to 4.3.7. Explanations of how these factors affected sustainability of DWS services in the case WSSs are also given in these sections. The explanations are summarised in the current reality tree for sustainable DWS services constructed as per the description in chapter 3. The constructed current reality tree is in figure 6.

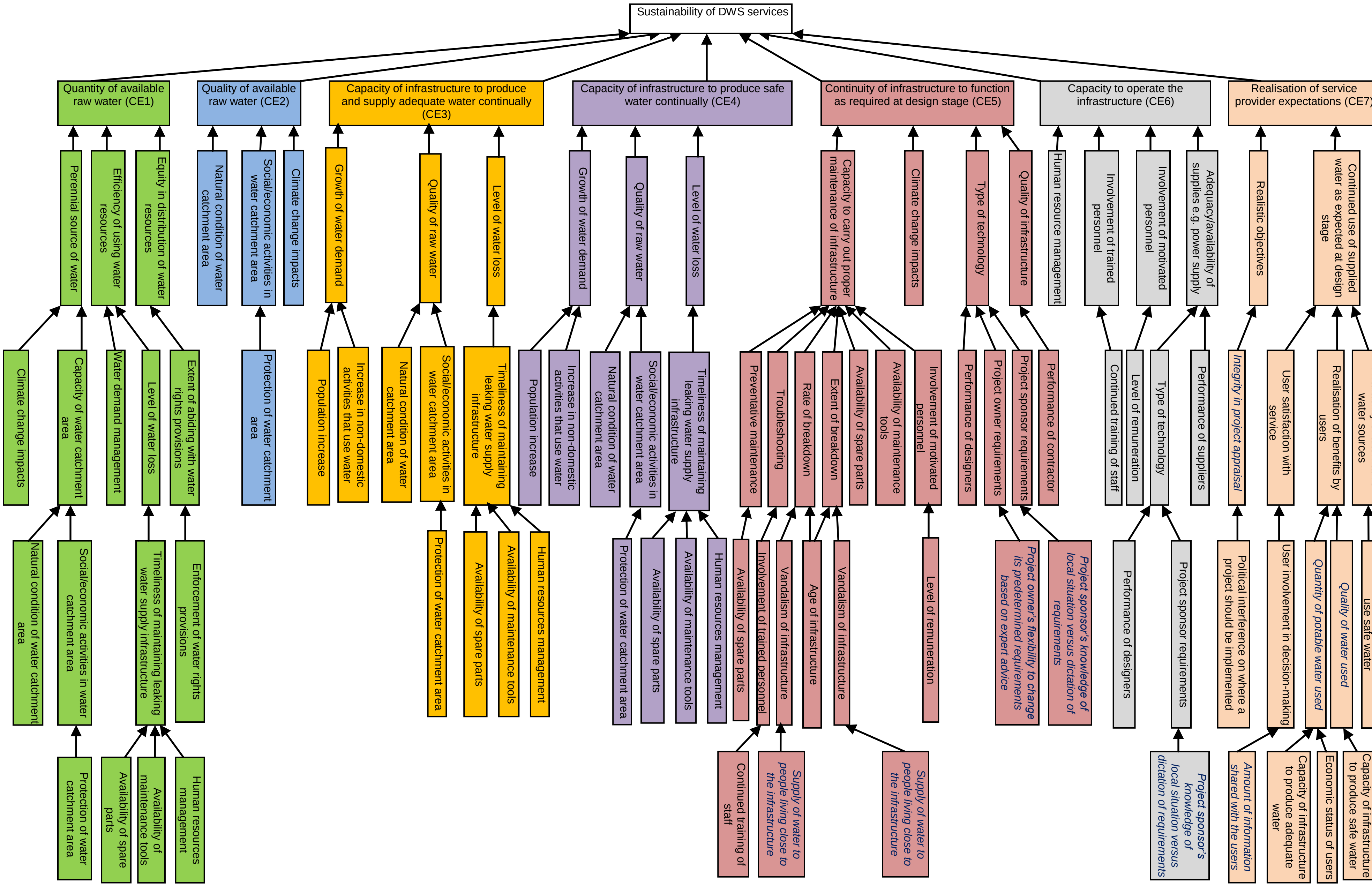


Figure 6: Current reality tree for the factors that affect sustainability of DWS services Source: Author

Figure 6 shows that some factors affected other factors, which in turn affected yet other factors. This went on and on until the 7 combined effects that affected sustainability of DWS services directly (figure 5) were triggered. This is corroborated by Harvey et al (2002) and Lockwood (2003). Harvey et al (2002) state that some factors depend on other factors while Lockwood (2003) states that factors are in a hierarchy.

The factors in figure 6 with their letters upright were highlighted in the literature as affecting sustainability of DWS services, and have also been identified as such in the case WSSs. On the other hand, the factors with their letters in italics were not highlighted in the literature but have been identified as affecting sustainability of DWS services in the case WSSs. The latter factors were mentioned by the respondents and fitted very well in the current reality tree (figure 6). The fact that the factors fitted in the current reality tree shows that the factors played a role in affecting sustainability of DWS services, otherwise the factors would not fit. The factors identified in this research are:

AF1 - Integrity in project appraisal;

AF2 - Project owner's flexibility to change its predetermined requirements based on expert advice;

AF3 - Project sponsor's knowledge of local situation versus dictation of requirements;

AF4 - Quantity of potable water used;

AF5 - Quality of water used;

AF6 - Supply of water to the people living close to the water supply infrastructure; and

AF7 - Amount of information shared with the water users.

The part played by these factors in affecting sustainability of DWS services are discussed in sections 4.3.1 to 4.3.7.

When the factors identified in this research are combined with those already identified in the previous studies (table 10), the total number of the factors that affect sustainability of DWS services becomes 70 (63+7). Fifty five (55) of the 70 factors have cause-and-effect relationships and these have been included in figure 6. The other 15 factors do not have the cause-and-effect relationships and as such have not been included in figure 6. The 15 factors which have not been included in figure 6 are the following:

1. Continuous upgrading of infrastructure;
2. Proper handover of infrastructure from contractor to project owner;

3. Water demand management;
4. Involvement of appropriate stakeholders to assess and address risks;
5. Lessons from previous projects/organisational learning;
6. Involvement of senior managers in a project;
7. Supportive legislation/policies;
8. Availability/use of adequate financial resources;
9. Management arrangement (type) of water supply system;
10. Safety of workers;
11. External support;
12. Supervision of subordinates;
13. Organisational culture;
14. Demand-responsive approach; and
15. Inter-community competitions.

Factors 1 to 6 have not been included in figure 6 because they are tactics for improving sustainability of DWS services and not the causes of sustainability failure of DWS services. Similarly, factors 7 to 12 have not been included in figure 6 because they are not the causes of sustainability failure of DWS services but are the requirements for effective implementation of the strategies and tactics for improving sustainability of DWS services. Therefore, factors 1 to 6 will be discussed in sections 4.3.1 to 4.3.7 and factors 7 to 12 will be discussed in section 4.4.

On the other hand, factors 13 to 15 have not been included in figure 6 because the respondents felt that these factors did not have influence on the sustainability of DWS services in Malawi.

Figure 6, being a current reality tree, shows the root causes of unsustainable DWS services. The root causes are the factors which appear at the end of the cause-and-effect chains (Duffy et al, 2012). These root causes are discussed in sections 4.3.1 to 4.3.7.

Where more than one root cause affected a particular factor in the interaction that led to a particular combined effect (e.g. availability of spare parts, availability of maintenance tools, and human resources management affected timeliness of maintaining leaking water supply infrastructure which after affecting other factors eventually affected quantity of available raw water), principal component analyses were conducted. The critical assumptions underlying the analysis were tested and confirmed using the Kaiser-Meyer-

Olkin (KMO) measure of sampling adequacy (in all cases KMO was greater than 0.5) and Bartlett Test of Sphericity (in all cases the associated probability was less than 0.05). The aim of the analyses was to check the level of influence of each of the root causes. The researcher decided, as it is the case in most similar studies, a cut-off loading of 0.5 to screen out variables that were weak (Bryde, 2008; Ika et al, 2011). The analyses were based on the responses from the analytical survey which is described in chapter 3.

For availability of spare parts, availability of maintenance tools, and human resources management as root causes of (1) inadequate quantity of available raw water, (2) insufficient capacity to produce and supply adequate water, and (3) insufficient capacity to produce safe water, the results of principal component analyses show the loadings of the root causes as follows:

- Availability of spare parts = 0.9;
- Availability of maintenance tools = 0.9; and
- Human resources management = 0.6.

For population increase, and increase in non-domestic activities that used water as root causes of (1) insufficient capacity of infrastructure to produce adequate water, and (2) insufficient capacity of infrastructure to produce safe water, the results of principal component analyses show the loadings of the root causes as follows:

- Population increase = 0.8; and
- Increase in non-domestic activities that used water = 0.8.

For capacity of infrastructure to produce adequate water, and economic status of water users as root causes of failure to realise service provider expectations, the results of principal component analyses show the loadings of the root causes as follows:

- Capacity of infrastructure to produce adequate water = 0.8; and
- Economic status of water users = 0.8.

These loadings (being greater than 0.5) mean that all the above root causes contributed strongly to the combined effects. As such, all the above root causes are considered valid.

Overall, there are 26 root causes of unsustainable DWS services in Malawi. The 26 root causes (not in any order of importance) are:

RC1 - Failure to protect water catchment areas;

RC2 - Wasteful usage of water;

RC3 - Unavailability of spare parts;

RC4 - Unavailability of appropriate maintenance tools;

RC5 - Number of personnel that does not consider amount of work to be carried out;

RC6 - Failure to issue and regulate water rights for some water users;

RC7 - Poor natural condition of water catchment areas;

RC8 - Climate change impact - decrease in rainfall;

RC9 - Increased population;

RC10 - Increased non-domestic activities that use water;

RC11 - Limited continued training of staff;

RC12 - Low remuneration;

RC13 - Water not supplied to people living close to the water supply infrastructure;

RC14 - Use of infrastructure beyond its useful life span without refurbishment;

RC15 - Poor performance of designers;

RC16 - Project owner's refusal to change its predetermined requirements in spite of the experts' advice;

RC17 - Project sponsors who do not have adequate knowledge of local situation but insist to prescribe requirements;

RC18 - Poor performance by contractors;

RC19 - Climate change impact - extreme floods;

RC20 - Poor performance by suppliers;

RC21 - Political interference on where a project should be implemented;

RC22 - Limited information shared with water users;

RC23 - Limited capacity of infrastructure to produce and supply adequate water;

RC24 - Limited capacity of infrastructure to produce safe water;

RC25 - Poor economic status of water users; and

RC26 - Lack of political will on the need for people to use safe water.

While almost all the above root causes had already been identified by the researchers as some of the factors that affect sustainability of DWS services, their identification as the sustainability failure root causes, has been done in this study. The identification of the root causes will assist to address the underlying issues that affect sustainability of DWS services in Malawi. This will ensure that the problem of sustainability failure of DWS services will be solved completely (Dew, 1991; Doggett, 2005). The root causes are discussed in sections 4.3.1 to 4.3.7.

Box 16 shows the dates when some of the respondents noted for the first time that DWS services were not sustainable in some of the case WSSs.

Box 16: Quotations on the dates when DWS services were noted not sustainable

> "…water supply is available only for 3 hours per day from 2am. I found this problem already in existence in 1999 when I started living here" (Respondent No. 23)
>
> "I have been here since 2003 but we found the water supply problem already in existence" (Respondent No. 27)

The quotations in box 16 show that, by the time of this study (2014), sustainability failure of DWS services had been occurring in some of the case WSSs for not less than 15 years. However, despite the sustainability challenges having been there for a long time, the challenges had not been resolved. The reasons why the sustainability challenges had not been resolved are also discussed in sections 4.3.1 to 4.3.7.

The last topics that are discussed in sections 4.3.1 to 4.3.7 are the proposed strategies for managing the combined effects, and the tactics for dealing with the root causes of sustainability failure of DWS services in Malawi.

The factors, root causes, and proposed solutions are discussed under the 7 combined effects as follows:

4.3.1 Quantity of available raw water (CE1)

4.3.1.1 Factors that affected quantity of available raw water

The quotations in box 17 show the factors that affected the quantity of available raw water in the case WSSs.

Box 17: Factors that affected quantity of available raw water

> "The amount of raw water flowing into the dam is noted to be getting less and less as a result of climate change impacts" (Respondent No. 12-8)
>
> "… We realise that there may not be enough water to fill the dam because of decreasing rainfall pattern. …The rains are on the declining trend because of climate change impacts" (Respondent No. 3-8)
>
> "We will have to do a lot of catchment protection works … to sustain quantity of available

raw water" (Respondent No. 3-6)

"Boreholes are low yielding because of hydro-geological nature of the ground. The yields are getting worse with passage of time…" (Respondent No. 3-6)

"…the yields from the boreholes are not adequate … because the aquifers are not good" (Respondent No. 13-5)

"Experts told us that additional water would not be stored even if the existing dam was raised. This is the case because the hydrology capacity of the catchment area has been used in full" (Respondent No. 12-8)

"The river dries up during dry season because the catchment area is small and degraded. The catchment is not a protected area and it has degraded because of wanton cutting down of trees" (Respondent No. 13-5)

"Quantity of raw water keeps reducing with passage of time because of degraded catchment area ..." (Respondent No. 13-5)

"There is serious deforestation in the catchment area for the water source. The catchment area used to be a forest area with indigenous trees managed by the department of forestry" (Respondent No. 9-5)

"... farmers divert water for irrigation from upstream of the river from which we abstract raw water. Last year, instead of taking water to their gardens through furrows, they blocked the whole river and there was no water at our abstraction point for a week" (Respondent No. 11-12)

"... because of cultivation in the water catchment area, during the dry season the water does not reach our water intake point because all the water is used for watering crops upstream …Consequently, this water supply system is constantly without water when actually there is plenty water in the river" (Respondent No. 2-12)

"Cultivation in the water catchment area has led to heavy siltation of the dam which has reduced the volume of water stored" (Respondent No. 6-1)

"...people went into the water catchment area cutting down trees wantonly, arguing that the catchment area was harbouring thugs. The whole catchment area was deforested and people started farming in the catchment area. As a result, soil was eroded into the dam, fertilizers went into the dam and the growth of weeds in the dam multiplied. The consequence is that one-third of the dam is silted, the quality of water went bad, the rivers which contribute water that flows into the dam are no longer perennial" (Respondent No. 1-1)

"The river dries up during the dry season these days because of catchment degradation. The catchment area is so degraded as it is now inhabited and the inhabitants cultivate right in the catchment area" (Respondent No. 21-7)

"The source of water for this water supply system dries up completely during dry season due to catchment degradation and inadequate rains" (Respondent No. 14-7)

"The catchment area for the water source for this water supply system is not protected. As such, trees have been cut down and there is cultivation in the river bank. These have resulted in high soil erosion which leads to siltation" (Respondent No. 14-7)

"...those whose water is paid for by institutions use much more than assumed because water is wasted in their homes" (Respondent No. 12-8)

The quotations in box 17 show that the quantity of available raw water was not adequate in some of the case WSSs because:

i. The water catchment areas were not protected;
ii. Social/economic activities such as cultivation and cutting down of trees were allowed to take place in the water catchment areas;
iii. The quantities of water abstracted from some sources had reached the limits that the catchment areas could provide by their nature;
iv. The water catchment areas had degraded to the extent that they could not provide as much water as they used to do;
v. Less rainfall was received;
vi. Water was used wastefully by some users;
vii. Some water sources were no longer perennial; and
viii. Water resources were not shared equitably amongst the users.

In addition to the above reasons, the quantity of raw water in the case WSSs was not adequate because of high water losses. Records show that in 2013 water losses in the case WSSs were as shown in table 23.

Table 23: Water losses in the case WSSs in 2013

Case WSS No.*	Water loss
1	30%
2	21%
3	20%
4	47%
5	37%
6	26%
7	30%

Note:

* These numbers are used to distinguish one case WSS from another and not to identify the systems. The water losses shown are for 7 case WSSs because water flows in the other 3 case WSSs were not measured.

Source: Records kept by the Scheme Managers

Table 23 shows that water losses in the case WSSs ranged from 20% to 47% in 2013. Water losses in 5 of the 7 case WSSs (where water losses were calculated) were higher than 23% which is the acceptable water loss percentage for the developing countries (Banerjee et al, 2008). High water losses led to inefficient use of water resources as more water was abstracted from the sources than it should have been to compensate for the lost water.

The above means that there were two more reasons why the quantity of raw water in the case WSSs was not adequate, namely:

ix. High water losses; and
x. Inefficient use of water resources.

This implies that, overall, the quantity of available raw water in the case WSSs was affected by how protected a water catchment area was, social/economic activities taking place in a water catchment area, natural condition of a water catchment area, capacity of a water catchment area, climate change impacts, wasteful usage of water, how perennial a water source was, equity in distribution of water resources, level of water loss, and efficiency of using water resources. These factors need to be managed for the quantity of available raw water to be sustained.

4.3.1.2 Consequence of not managing the factors

The factors that affected the quantity of available raw water were not managed as required in some of the case WSSs as discussed in section 4.3.1.4. The consequence of not managing the factors in the required manner was that the quantity of available raw water was not adequate (Cq 1). This was the situation in 4 of the 10 case WSSs.

4.3.1.3 Strategy for managing quantity of available raw water

Ensuring that raw water for DWS is always in sufficient quantity to satisfy the demand and is at a place from where it can be supplied in a cost-effective way (**S1**)

This strategy is supported by Abrams (1998) who advises that the same quantity of raw water should be available reliably regardless of the length of time which might have elapsed from the time the project was designed. To ensure that there is always adequate quantity of raw water, the root causes of inadequate quantity of available raw water should be addressed. The paragraphs that follow discuss the root causes and the proposed tactics for addressing them:

4.3.1.4 Root causes and how to manage them

This study has found out that there were 8 root causes of inadequate quantity of available raw water in the case WSSs. The 8 root causes as well as the other 8 factors that affected sustainability of the quantity of raw water in the case WSSs are shown in figure 7, which is an extract from figure 6.

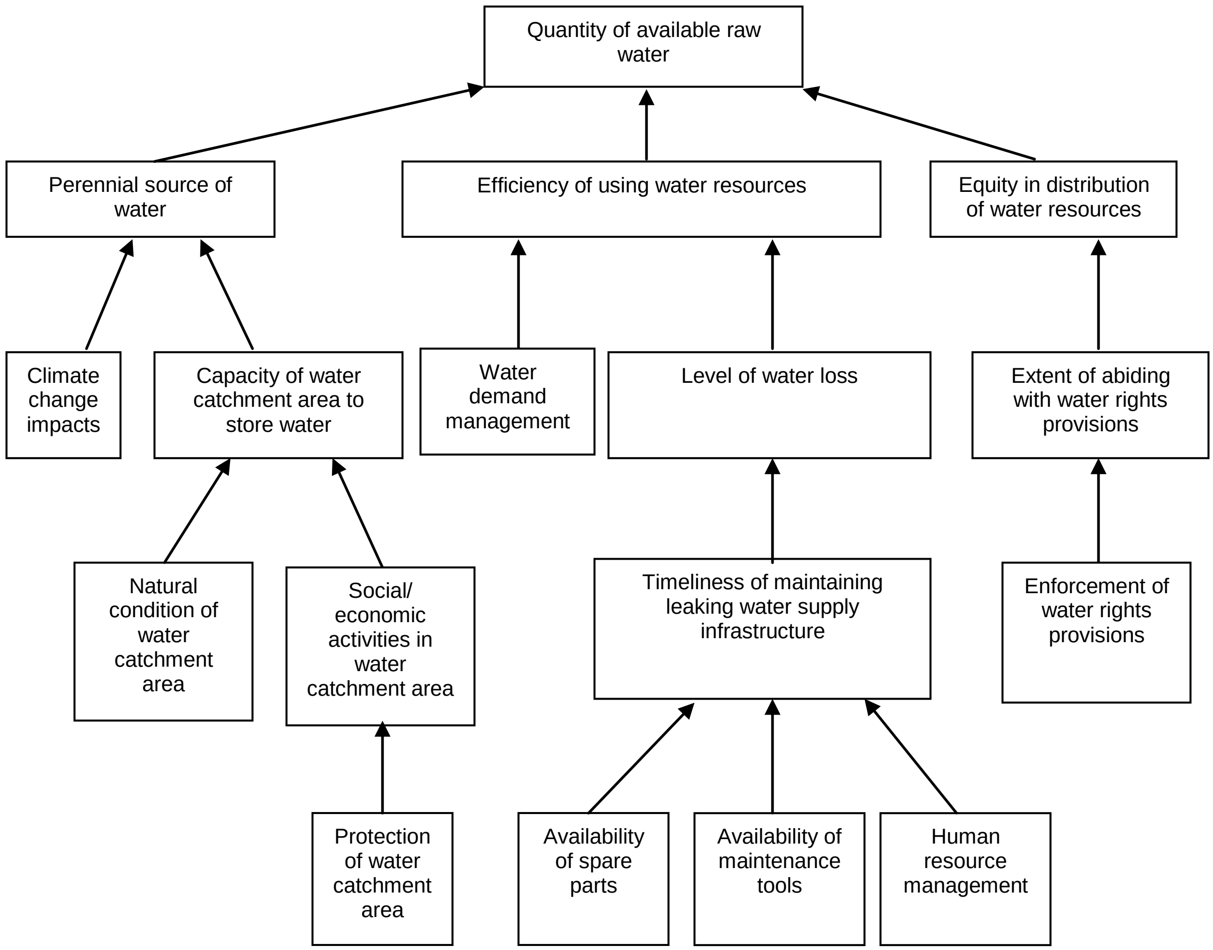


Figure 7: Relationship of the factors that affect the quantity of available raw water

The 8 root causes of sustainability failure of the quantity of raw water, the reasons why they could not be addressed, and the proposed tactics for managing them are as follows:

1. *Root cause 1 for inadequate quantity of available raw water* - Failure to protect water catchment areas (RC1)

Water catchment areas for 4 of the 6 case WSSs, where water sources were rivers and dams (quantity of available raw water where the water sources were Lake Malawi and boreholes seemed not affected by how protected a water catchment area was), were not protected. As such, people settled, cultivated, and/or carried out other social/economic activities in those water catchment areas freely. As indicated by some respondents, this led to reduction of available raw water. This was so because the social/economic activities that took place in the catchment areas, among others, made the soil in the catchment areas prone to erosion. Soil erosion resulted in silts being deposited onto the river bed. Consequently, water flowed through the silts making the flow to be subsurface. This resulted in minimal or no surface flow at all. In one of the case WSSs, the water abstraction point was relocated to the upstream of the initial point where the river surface flow was bigger. The river surface flow was bigger at the new location because there was no siltation as the catchment area there was protected (i.e. there was a forest reserve).

In addition to siltation, the decrease of the quantity of raw water, where water catchment areas were not protected, resulted from deforestation of the catchment areas. Deforestation of the catchment areas made rainwater to flow downstream quickly instead of percolating into the ground. This was the case because water infiltration and retention capacity, which the soils had when the area was forested, was no longer there (Wahl et al, 2005). Increased run-off resulted in the catchment areas as well as the water sources drying up earlier than they used to do when the catchment areas were forested (Baumann and Danert, 2008).

Further, built-up areas in the water catchment areas reduced permeability and therefore increased run-off (Stephenson, 2003). Consequently, not much water was stored in the water catchment areas and the water sources. As such, the available raw water was not adequate throughout the year.

Substantiating "failure to protect water catchment areas" as a root cause: If the water catchment areas were protected, social/economic activities could not have taken place in the catchment areas. As such, the water catchment areas should not have degraded. The catchment areas which are not degraded should have been able to store adequate water, hence the water sources would have been perennial (Braune and Xu, 2010). Raw water would then be adequate. Therefore, failure to protect water catchment areas was one of the root causes of inadequate quantity of available raw water.

Efforts at the time of the study to protect water catchment areas

The DWS service providers, for the case WSSs where the water catchment areas had been encroached, stated that there was nothing that they could do to protect the catchment areas. They said that protection of water catchment areas needed support from politicians because some politicians told people to encroach and/or not to stop encroaching the catchment areas unless they were paid compensations. Although the politicians said this, compensations had already been paid for the affected catchment areas. As such, the DWS service providers gave up on protecting the catchment areas at the time and hoped the issue would be resolved later once there would be a politician(s) who would appreciate the importance of protecting water catchment areas. However, dependence on the availability in the political arena of people who appreciate the importance of protecting water catchment areas is not sustainable. This is the case because the dates and the period that such people would be available could not be guaranteed. However, even without such politicians, water catchment areas can be managed successfully as it was the situation at one of the case WSSs. Details of how the catchment area was managed are covered below under proposed tactics.

The reasons why water catchment areas could not be protected

The water catchment areas in the affected 4 case WSSs could not be protected because:

i. The catchment areas were not declared protected areas in the manner required by law; and
ii. There was no mechanism for enforcing by-laws for protecting catchment areas.

Proposed tactics for ensuring protection of water catchment areas

a - Declare water catchment area as a protected area (T1)

The first step to protect a water catchment area is to declare the concerned area a protected area. Relevant legislation should be followed in the process of declaring an area a protected area. An area is legally recognised as a protected area when it is indicated as such in the Government of Malawi's Gazette (Government of Malawi, 1997a). Otherwise, as it was the case in the affected 4 case WSSs, the water catchment areas were assumed to be protected areas when in fact they were not. This is the case because not all legal requirements were satisfied. As such, there was no legal backing to manage the water catchment areas. Therefore, there is a need that all legal requirements should be satisfied to the extent that the water catchment areas are gazetted as protected areas.

b - Manage water catchment area (T2)

Once a catchment area is declared a protected area, mechanism should be put in place on how to manage the catchment area. The best practice from one of the case WSSs is that the protected area should be a forest reserve. Once a protected area becomes a forest reserve, the area is managed by the Forestry Department staff deriving powers from the Forest Act (Government of Malawi, 1997a). The challenge, though, has been lack of financial resources in the Forestry Department. As such, in the best practice case WSS, the DWS service provider had been providing financial resources.

Apart from providing financial resources, the DWS service provider also worked with the Forestry Department to undertake catchment rehabilitation activities such as re-afforestation and soil erosion control. This is supported by Kenel and Whitherspoon (2005) who state that the protected areas should not only be managed by those assigned to do so (in Malawi's case Forestry Department) but also by DWS service providers. This is important as water availability depends on how water resources are managed (Arnell and Delaney, 2006). Morita-Lou and Waters (2008) state that protection of catchment areas and water sources are essential activities that enhance sustainability of DWS services.

In addition, surrounding communities were allowed to enter the forest area to collect forest products after satisfying some conditions. Such conditions included payment of a fee, collecting only dead wood, and not carrying into the forest tools that could be used to cut down trees. Collection of forest products from the forest reserve by the surrounding communities made them to appreciate the importance of having forest areas. Such people would not carry out activities that would degrade forest areas.

2. *Root cause 2 for inadequate quantity of available raw water* - Wasteful usage of water (RC2)

Some respondents reported that some water users in the case WSSs used water wastefully. It was reported that such users let water run to waste and/or did not repair leaking facilities. This was the case mostly where the costs for the water were not covered by the users directly. An example of wasteful usage of water can be noted in table 13. The household for one of the participants to the focus group discussions used 304 litres of water per capita per day (not necessarily the highest consumption figure in the case WSSs). Although not compared to any standard figure, this is quite high as it is more than the average consumption figures for most countries. The only countries where average water consumption figures were higher than 304 litres of water per capita per day were United States of America, Australia, Italy, Japan, Mexico and Spain (UNDP, 2006). The consequence of wasteful usage of water is that, to compensate for the wasted water, more water was abstracted from the sources which was inefficient use of water resources.

Substantiating "wasteful usage of water" as a root cause: If the water was not used wastefully, there would be efficient use of water resources. As such, there would be adequate raw water (Butler and Memon, 2006). Therefore, wasteful usage of water was one of the root causes of inadequate quantity of available raw water.

The reason why wasteful usage of water could not be controlled

The problem of wasteful usage of water could not be solved because DWS service providers felt the overall average consumption figures in the WSSs did not suggest wasteful usage of water to warrant any action. This is supported by Banerjee et al (2008) who state that water consumption in the Sub-Saharan Africa, at just over 150 litres per capita per day, cannot be regarded as wasteful to require water demand management.

Proposed tactics for controlling wasteful usage of water

While more elaborate activities for water demand management like sensitising people to close taps while brushing teeth, use small cisterns for toilets, wash vehicles using buckets, and others, may wait until the average consumption figures are well over 150 litres per capita per day as advocated by Banerjee et al (2008), the following tactics should be employed even where the average consumption figure is low. The proposed tactics will result in efficient use of water resources at a low cost as the proposed activities are not complex.

a - Monitor water consumption figures for users (T3)

DWS service providers should check water consumption for each of the water users. When water consumption for a water user is too high, the service provider should assist the customer to identify the cause of high water consumption.

b - Maintain leaking facilities (T4)

If the cause of high water consumption is wasteful usage and/or leaking facilities, the service provider should advise the consumer to fix the problem or go into an arrangement whereby the problem could be fixed by the service provider at a fee payable to the service provider. The fee could be levied as part of a water bill. One respondent advises that *"people should be sensitised to repair the taps and toilets, and* *not let the water flow continuously due to malfunctioning of the taps and toilets"* (Respondent No. 22-9). This is supported by Butler and Memon (2006) who state that quantity of water can be made to satisfy the demand by controlling leakage.

3. *Root cause 3 for inadequate quantity of available raw water* - Unavailability of spare parts (RC3); and
4. *Root cause 4 for inadequate quantity of available raw water* - Unavailability of appropriate maintenance tools (RC4)

It was heard from some of the respondents that spare parts and appropriate maintenance tools were not available most of the time in the case WSSs. Baumann and Danert (2008) came up with similar finding in their study in Malawi. The common materials which were not available were pipes and joining fittings. It was difficult to find in stock pipes and joining fittings which were of the same types and sizes as the broken down ones. The respondents said, among other challenges, unavailability of spare parts and appropriate maintenance tools led to delayed maintenance of leaking water supply facilities. This was the case because in the absence of spare parts, maintenance works could not be carried out. However, water had to be allowed to flow through some of the leaking facilities so that users could continue to access potable water. This was necessary as sourcing of appropriate materials could take days, weeks, and sometimes months.

Similarly, as indicated above, appropriate maintenance tools were not available in the case WSSs most of the time. One piece of equipment which was not available in most case WSSs was an excavator. In the absence of appropriate maintenance tools, maintenance works took long to be completed. For example, in the absence of an excavator, the grounds where pipes were buried had to be dug manually. With this, excavation sometimes took longer than the actual maintenance works of the pipes. This is corroborated by Binder (2008) who states that lack of equipment affects the capacity to maintain infrastructure. The consequence of delayed maintenance of leaking facilities is that it contributes to high water losses. Water losses in the case WSSs ranged from 20% to 47% (table 23) compared to the acceptable 23% for developing countries (Banerjee et al, 2008). This means that more water was abstracted from the sources to cater for the lost water which was inefficient use of water resources.

Substantiating "unavailability of spare parts, and unavailability of appropriate maintenance tools" as root causes: If spare parts and appropriate maintenance tools were available, maintenance works for the leaking facilities would have been carried out on time, and water losses would not be high. If the water losses were not high, there would be efficient use of water resources. As such, there would be adequate raw water. This is supported by Arnell and Delaney (2006) who state that the quantity of available raw water can be increased by reducing leakage of water. Therefore, unavailability of spare parts and appropriate maintenance tools were some of the root causes of inadequate quantity of available raw water.

The reason why spare parts and appropriate maintenance tools were not available

Spare parts and appropriate maintenance tools were not available at the time they were required because it took long for these items to be purchased. This was the case because purchase of these items was not prioritised.

Proposed tactics for ensuring availability on time of spare parts and appropriate maintenance tools

a - Prepare a list of required spare parts and appropriate maintenance tools (T5)

A list of spare parts and appropriate maintenance tools required for maintenance of infrastructure should be prepared and given to the personnel responsible for purchase of these items.

b - Prioritise and enforce purchase of spare parts and appropriate maintenance tools (T6)

The responsibility of purchasing spare parts and appropriate maintenance tools should be given to a payment officer who should be under strict instructions to prioritise purchase of the listed items. The payment officer should be clearly told the consequences that he will face if the items would not be purchased on time. This tactic is expected to work because some respondents stated that spare parts and appropriate maintenance tools were not available on time simply because their purchase was not prioritised. This view was based on the fact that payments in the amounts more than that required for the purchase of spare parts and maintenance tools were made at the time paying officers claimed that there was no money.

5. *Root cause 5 for inadequate quantity of available raw water* - Number of personnel that does not consider amount of work to be carried out (RC5)

The numbers of personnel working on maintenance works compared to the total numbers of personnel in the case WSSs were as shown in table 24.

Table 24: Personnel working on maintenance works in the case WSSs

Case WSS Number*	Personnel working on maintenance work	Other personnel	Total number of personnel
1	2	14	16
2	1	11	12
3	12	124	136
4	2	8	10
5	3	15	18
6	1	7	8
7	1	5	6
8	32	431	463

Note:

* These numbers are used to distinguish one case WSS from another and not to identify the systems. The numbers of personnel shown are for 8 case WSSs because the workers in 1 case WSS were volunteers whose number was not fixed, and there were no workers at one case WSS because the system was no longer operational.

Source: Records kept by the Scheme Managers

Table 24 shows that the numbers of personnel allocated to carry out maintenance works were generally few compared to the total numbers of personnel in the case WSSs. As such, the personnel that carried out maintenance works were not adequate in some of the case WSSs. For example, one of the case WSSs where there was only one personnel who worked on maintenance works had 768 connections and served 32,436 people. The pipe network for this case WSS was too extensive to be maintained by one person. This resulted in delayed implementation of maintenance works. Consequently, a lot of water was lost. This led to inefficient use of water resources as more water was abstracted from the sources to cater for the lost water.

Substantiating "Number of personnel that does not consider amount of work to be carried out" as a root cause: If the number of personnel allocated to carry out maintenance works was adequate, maintenance works would be carried out on time, and not much water would be lost. Hence, there would be efficient use of water resources. Therefore, number of personnel that does not consider the amount of work to be carried out was one of the root causes of inadequate quantity of available raw water.

The reason why the number of personnel could not match the amount of work carried out

The number of personnel could not match the amount of work carried out because either the total number of staff was not adequate or the staff members were not allocated equitably amongst the sections of the DWS institutions.

Proposed tactic for matching the number of personnel with the amount of work to be carried out

a - The number of staff should be based on the amount of work to be carried out (T7)

The number of staff should be based on the amount of work to be carried out in each section of a DWS institution. A thorough review of the work to be carried out should be conducted, preferably by people with vast experience in the field. The number should be checked and approved by a regulator who should ensure that the number is optimum. Thereafter, there is need for regular review of the number. Otherwise, deciding the number without considering the amount of work to be carried out results in either excessive or inadequate staff members. An example of inadequate members of staff is where a plumber doubling as a driver, in one of the case WSSs, was assigned to carry out pipeworks in a WSS serving 32,436 people.

As regards the recommendation that the number of staff should be a maximum of 6 per 1,000 connections (Banerjee et al, 2008; Cleaver and Toner, 2006), it should be noted that this does not work well in some circumstances. For example, 12 staff members working for a community-managed water supply system serving 32,436 people through 768 connections translates into 16 staff members per 1,000 connections. This means that 12 staff members for this WSS were almost three times as many as what is recommended. However, looking at the technology that was used (supply of water by gravity which necessitated the intake to be 2km into the mountains), and the sparse type of settlements where the water users lived, the recommendation of 6 staff members per 1,000 connections would not work. The best way is to assess each WSS and then decide the appropriate number of staff members based on the amount of work to be carried out in each section.

Means of sourcing funds for paying the required number of staff where the generated revenue is not enough are discussed in section 4.4.5.

6. *Root cause 6 for inadequate quantity of available raw water* - Failure to issue and regulate water rights for some water users (RC6)

Some respondents stated that water rights were not regulated for some water users. As such, some entities took advantage of this weakness to violate water rights of others. For example, farmers in one case WSS diverted all the water from a river into their gardens upstream of the water abstraction point for the case WSS. This was the situation despite that the water in the river would be adequate for both farming and drinking water supply if furrows were used to convey water to the gardens.

Substantiating "failure to issue and regulate water rights for some water users" as a root cause: If water rights were issued to all water users and regulated, the licensees would have abided by the stipulations in their water rights. If the licensees abided by the stipulations in their water rights, water resources would have been shared equitably, and there would be adequate raw water for all the uses including drinking water supply (WSSCC, 2010). Therefore, failure to issue and regulate water rights for some water users was one of the root causes of inadequate quantity of available raw water.

The reason why water rights were not issued and regulated for some water users

Water rights were not issued and regulated for some water users because it was deemed that the quantities of water that would be required by those users would not be much. This assumption was made because the water would be used for domestic purposes (Government of Malawi, 2013). As such, it was felt that issuance of water rights to such users would be increasing the workload without justification. The respondents stated that this supposition was supported by the fact that for a long time, people who used water for domestic purposes, used very little water and did not cause any problem to the other water users. The Water Resources Board actually claimed that violation of other people's water rights was a new and isolated phenomenon. They, therefore, expressed the need to be urgently informed by the well-wishers of any violation of the water rights so that they could act on the issues accordingly. They indicated that there were adequate rules and regulations to deal with such issues.

Proposed tactic for preventing violation of other water users' water rights

a - DWS service providers should be proactive in ensuring that their water rights are not violated (T8)

The responsibility of providing and enforcing water rights in Malawi rests with the National Water Resources Authority (Government of Malawi, 2013). However, being an interested party, a DWS service provider should find out who else abstract water from the source where raw water for DWS is abstracted. This information should be collected from the National Water Resources Authority and compared to the actual entities that abstract water on the ground. It should be the responsibility of the DWS service provider to quickly request the National Water Resources Authority to act whenever their water rights are violated by other entities. Otherwise, waiting for the farmers to divert the whole flow of water from the stream for a week, as it was the situation in one of the case WSSs, was not being proactive on the part of the DWS service provider.

7. *Root cause 7 for inadequate quantity of available raw water* - Poor natural condition of water catchment areas (RC7)

The nature of the catchment areas affected the quantity of available raw water in some of the case WSSs. In some of the affected case WSSs, the catchment areas were too small to provide the required quantity of raw water. One respondent stated that additional water would not be stored even if the existing dam was raised because the hydrology capacity of the catchment area had been used in full. Hodgkin (1994) elaborates that this is the case because each water catchment area has inherent physical limits to water source development. This was applicable in 4 of the 6 case WSSs where water sources were rivers and dams.

For the WSSs which used groundwater, the quantity of available raw water was not adequate because of the hydro-geological nature of the aquifers. This is supported by Chilton and Foster (1995) and Lloyd (1999) who state that poor borehole yields are most of the time due to hydro-geological nature of the aquifers. This was applicable in 1 of the 2 case WSSs where water sources were boreholes. The water yields from the boreholes dropped drastically within a few months of the boreholes having been drilled.

In both cases (where the catchment areas were too small, and where the aquifers did not yield much water), the available raw water was not perennial resulting in inadequate available raw water during some part of the year.

Substantiating "poor natural condition of water catchment areas" as a root cause: If the water catchment areas were not too small or not yielding less water because of their nature, the water sources would have been perennial, and there would be adequate raw water. Therefore, poor natural condition of water catchment areas was one of the root causes of inadequate quantity of available raw water.

The reason why no solution had been found for dealing with limited quantity of water from the catchment areas with poor natural condition

The quantity of water from the catchment areas with poor natural condition remained limited because it would not be easy to improve the nature of the catchment areas in the short term.

Proposed tactics for dealing with limited quantity of water from catchment areas with poor natural condition

a - Monitor the trend of the quantity of available raw water (T9)

DWS service providers should establish the trend of the quantity of available raw water. This is supported by Jiménez and Pérez-Foguet (2011) who state that availability of water resources need to be assessed. Monitoring of the trends of the available quantity of raw water is not expected to pose any challenge in Malawi in that the biggest segment of the respondents in the descriptive survey (35%) stated that the quantity of raw water was already being measured on a daily basis. The only problem was that the collected data was not analysed in a regular manner. Thirty nine percent (39%) of the respondents in the descriptive survey (the largest segment) stated that there was no time schedule for analysing the data collected on the quantity of available raw water. It is proposed that the collected data should be analysed on a monthly basis in order to establish and monitor the trends of the quantity of available raw water.

b - Develop and use alternative/additional water source (T10)

Where the quantity of raw water from an existing source is not adequate due to the nature of the catchment area, alternative water source should be developed and used. One respondent stated that *"to improve water supply to one hard-hit area, boreholes are being drilled to supply water to this specific area"* (Respondent No. 6-1). Another respondent added that *"the lasting solution is development of additional raw water source..."* (Respondent No. 1-1). Development and use of alternative/additional water source is supported by Arnell and Delaney (2006) who state that quantity of available raw water can be increased by developing new water sources.

c - Authorities responsible for land development should be advised not to allow additional people and developments in the affected area (T11)

If development of an alternative water source is not cost-effective, the DWS service provider should advise the authorities responsible for land development that additional people should not be allowed to settle in the affected area, and further developments should also not be allowed. Limiting the number of people and developments to be served by a WSS will ensure that there will be no growth in the water demand. One respondent stated that *"the water that we provide in this area is adequate for the demand because we have limited the extent of the supply area"* (Respondent No. 11-4).

d - Relocate the affected settlement to a new area (T12)

In addition to or instead of limiting the number of people and developments to be served by the affected WSS, a new settlement should be established where there is a water source with adequate and good quality raw water, which can be supplied in a cost-effective manner. One interviewee stated that *"if it was possible, this town should be moved to where there is sustainable raw water"* (Respondent No. 8-6).

Movement of a settlement to another place will not be new because the City of Jerusalem was at one time (during the Middle Bronze and Iron Ages) relocated so that it would be at a site where it could receive water from the springs using newly constructed aqueduct (Barghouth and Al-Sa`ed, 2009).

e - Government should provide financing for DWS systems which are not cost-effective (T13)

If government decides that a settlement cannot be relocated, the government should take responsibility of covering the shortfall in the required funds (for investment, operation and maintenance, and replacement) for managing a WSS which is not cost-effective. In this regard, a WSS may not be cost-effective because raw water is sourced from a distant and/or low-lying place. The costs should be borne by the government because it would be unfair to ask the water users to pay the costs of managing a WSS which is known not to be cost-effective.

8. Root cause 8 for inadequate quantity of available raw water - Climate change impact - decrease in rainfall (RC8)

Some respondents cited climate change as one of the causes of inadequate quantity of available raw water in some of the case WSSs. The impact of climate change that has a direct effect on the quantity of available raw water is rainfall amount (Christensen et al, 2007). As such, the general trend of rainfall in the 10 case WSSs from 1960 to 2011 was checked and is shown in table 25.

Table 25: Trend of rainfall in the case WSSs from 1960 to 2011

Meteorological station within/close to the following WSS	Rainfall trend	% decrease based on the general trend	% increase based on the general trend
Chitipa	Decreasing	22.5	-
Ighembe	Decreasing	34.9	-
Nkhamanga-Lunyina	Decreasing	33.6	-
Mzuzu	Decreasing	13.5	-
Chintheche	Decreasing	5.0	-
Salima	Increasing	-	2.1
Chipoka Town	Decreasing	14.6	-
Chipoka Rural	Decreasing	14.6	-
Mudi	Increasing	-	3.5
Chiradzulu	Decreasing	34.4	-

Source: Compiled by the author based on the data collected from the Malawi Meteorological Department

Table 25 shows that there was a general decreasing trend of rainfall in 8 of the 10 case WSSs. At the time of this study, water sources were not perennial in 4 case WSSs. Three of the 4 case WSSs where raw water sources were not perennial were in the areas where there was a decreasing trend of rainfall. The number of the case WSSs where the water sources were no longer perennial and at the same time there was a decreasing trend of rainfall (3) is statistically not different to the total number of the case WSSs where water sources were no longer perennial (4). As such, it can be concluded that there was a relationship between failure of the water sources to be perennial in the 3 case WSSs and the decrease in the rainfall. After all, Braune and Xu (2010) and Lockwood (2003) state that the decrease in rainfall makes water levels in the dams and lakes to drop, river flows to decrease, and levels of groundwater to drop.

Substantiating "climate change impact - decrease in rainfall" as a root cause: If there was no decrease in rainfall, the water sources should have been perennial, and there would be adequate raw water throughout the year. Therefore, climate change impact - decrease in rainfall was one of the root causes of inadequate quantity of available raw water. This is supported by Lockwood (2003) and UNICEF-WHO (2011) who state that the quantity of available raw water reduces where there is low rainfall.

The reason why the decreasing trend of rainfall could not be reversed

The decreasing trend of rainfall could not be reversed because climate change impacts were irreversible in the short-term as noted by Chen et al (2010).

Proposed tactics for dealing with limited quantity of water resulting from decrease in rainfall

a - Monitor the trend of the quantity of available raw water (T9) - *details are on page 111*

b - Construct water impoundment structures (T14)

If the projected trend of the available raw water shows that the flows of water in the rivers will not be adequate throughout the year because of decrease in rainfall, water impoundment structures should be constructed. This was done in 2 of the case WSSs and it resulted in increased quantity of available raw water. Bruggen et al (2010) as well as Turton and Henwood (2002) state that impoundment structures help to resolve the challenge of irregular availability of raw water.

Natural lakes are also very helpful in resolving the challenge of irregular availability of raw water. One respondent actually stated that *"raw water availability for this water supply system is not a problem because the water source is Lake Malawi which is vast"* (Respondent No. 3-2). It is, therefore, recommended that where there are natural lakes, comparison should be made whether to construct impoundment structures or tap raw water from the natural lakes.

c - Develop and use additional water source (T10) - *details are on page 111*

d - Authorities responsible for land development should be advised not to allow additional people and developments in the affected area (T11) - *details are on page 111*

4.3.2 Quality of available raw water (CE2)

4.3.2.1 Factors that affected quality of available raw water

The quotations in box 18 contain the factors that affected the quality of raw water in the case WSSs.

Box 18: Factors that affected quality of raw water

"... because of cultivation in the water catchment area, the water becomes dirty during the rainy season …" (Respondent No. 2-12)

"Cultivation in the water catchment area has the following consequences: water contains a lot of chemicals which come from fertilisers which encourage growth of plants in the dam resulting in stinking water" (Respondent No. 6-1)

"...people went into the water catchment area cutting down trees wantonly, arguing that the catchment area was harbouring thugs. The whole catchment area was deforested and people started farming in the catchment area. As a result, soil was eroded into the dam, fertilizers went into the dam and the growth of weeds in the dam multiplied. The consequence is that one-third of the dam is silted, the quality of water went bad, the rivers which contribute water that flows into the dam are no longer perennial" (Respondent No. 1-1)

"The catchment area for the water source for this water supply system is not protected. As such, trees have been cut down and there is cultivation in the river bank. These have resulted in heavy soil erosion which leads to siltation" (Respondent No. 14-7)

"...water flows through rocks which have calcium, and in the process calcium dissolves in the water" (Respondent No. 20-3)

The quotations in box 18 show that raw water was of poor quality in some of the case WSSs because:

i. The water catchment areas were not protected;
ii. Social/economic activities such as cultivation and cutting down of trees were allowed to take place in the water catchment areas; and
iii. Some rocks in the river course (water catchment area) affected the quality of water once the water flowed past/through them.

This implies that the quality of raw water in the case WSSs was affected by how protected a water catchment area was, social/economic activities taking place in a water catchment area, and natural condition of a water catchment area. These factors need to be managed for the good quality raw water to be sustained.

4.3.2.2 Consequence of not managing the factors

The factors that affected the quality of available raw water were not managed as required in some of the case WSSs as discussed in section 4.3.2.4. The consequence of not managing the factors in the required manner was that the available raw water was of poor quality (Cq 2). This was the situation in 4 of the 10 case WSSs.

4.3.2.3 Strategy for managing quality of available raw water

Ensuring that raw water for DWS is always of a quality that can be treated by the existing infrastructure in a cost-effective way (**S2**)

This strategy is supported by Abrams (1998) who advises that the same quality of water should be available reliably regardless of the length of time which might have elapsed from the time the project was designed. To ensure that there is always good quality raw water, the root causes of poor quality raw water should be addressed. The paragraphs that follow discuss the root causes and the proposed tactics for addressing them:

4.3.2.4 Root causes and how to manage them

This study has found out that there were 3 root causes of poor quality raw water in the case WSSs. The 3 root causes and one other factor that affected sustainability of the quality of raw water in the case WSSs are shown in figure 8, which is an extract from figure 6.

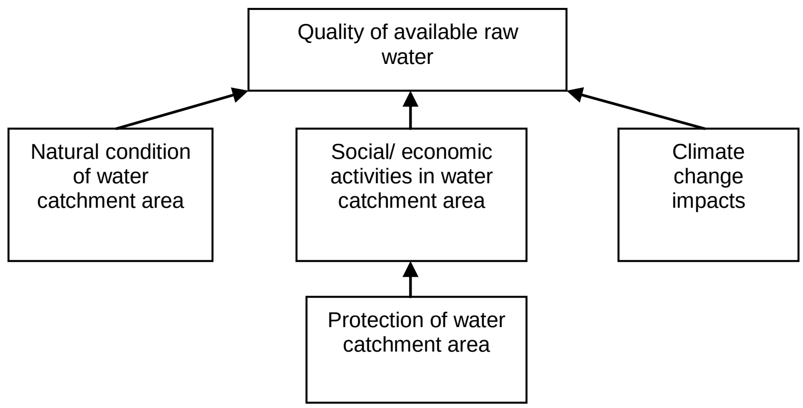


Figure 8: Relationship of the factors that affect the quality of raw water

The 3 root causes of sustainability failure of the quality of raw water, the reasons why they could not be addressed, and the proposed tactics for managing them are as follows:

1. *Root cause 1 for poor quality raw water* - Poor natural condition of water catchment areas (RC7)

Natural condition of a water catchment area affects the quality of raw water. For example, in one case WSS, when water flowed through the rocks situated in a section of the river course, calcium in the rocks dissolved in the water. From that point onwards, the water contained calcium.

Substantiating "poor natural condition of water catchment areas" as a root cause: If the natural condition of the water catchment area (e.g. presence of a particular type of rocks) would not result in contamination of the water, the quality of raw water would not be poor. Therefore, poor natural condition of water catchment areas was one of the root causes of poor quality raw water.

The reason why quality of raw water from the catchment areas with poor natural condition could not be improved

Raw water from the catchment area with poor natural condition remained of poor quality because it would be difficult and expensive to improve the natural condition of the catchment area and subsequently the quality of water.

Proposed tactics for dealing with the challenge of poor quality raw water abstracted from catchment areas with poor natural condition

a - Monitor the trend of the quality of available raw water (T15)

DWS service providers should establish the trend of the quality of available raw water. The established trend will assist the DWS service providers to decide whether or not to continue using the water. One interviewee stated that *"measurements of the quality of available raw water are used to decide as to when should an alternative water source be developed"* (Respondent No. 13-5).

Monitoring of the trends of the quality of raw water is not expected to pose any challenge in Malawi in that the biggest segment of the respondents in the descriptive survey (49%) stated that the quality of raw water was already being measured on a daily basis. The only problem was that the collected data was not analysed in a regular manner. Thirty six percent (36%) of the respondents in the descriptive survey (the largest segment) stated that there was no time schedule for analysing the data collected on the quality of raw water. It is proposed that the collected data should be analysed on a monthly basis in order to establish and monitor the trends of the quality of raw water.

b - Develop and use alternative/additional water source (T10) - *details are on page 111*

c - Relocate the affected settlement to a new area (T12) - *details are on page 112*

d - Government should provide financing for DWS systems which are not cost-effective (T13) - *details are on page 112*

2. *Root cause 2 for poor quality raw water* - Failure to protect water catchment areas (RC1)

Water catchment areas for 6 of the 8 case WSSs where the water sources were rivers, dams and boreholes (the catchment area for Lake Malawi is broad and is not only related to the surrounding areas for the water abstraction points for the case WSSs) were not protected. As such, people settled, cultivated, and/or carried out other social/economic activities in the water catchment areas freely. The above activities, among others, led to soil erosion. The consequence of soil erosion was that the water carried with it a lot of silts making the water turbid, which is a deterioration of water quality. Further, cultivation upstream of the water abstraction points led to deterioration of water quality in that chemicals like fertilisers applied in the gardens were washed into the water sources (World Bank, 2007). One interviewee stated that due to cultivation in the water catchment area, water in their dam contained a lot of chemicals from fertilisers which resulted in growth of plants in the dam hence stinking water.

Substantiating "failure to protect water catchment areas" as a root cause: If the water catchment areas were protected, social/economic activities could not have taken place in the catchment areas. As such, the quality of raw water would not be poor (Braune and Xu, 2010). Therefore, failure to protect water catchment areas was one of the root causes of poor quality raw water.

The reasons why water catchment areas could not be protected

The water catchment areas in 4 of the 10 case WSSs could not be protected because:

i. The catchment areas were not declared protected areas in the manner required by law; and
ii. There was no mechanism for enforcing by-laws for protecting catchment areas.

Proposed tactics for ensuring protection of water catchment areas

a - Declare water catchment area as a protected area (T1) - *details are on page 102*

b - Manage water catchment area (T2) - *details are on page 102*

3. *Root cause 3 for poor quality raw water* - Climate change impact - decrease in rainfall (RC8)

As indicated in section 4.3.1, there was a decreasing trend of rainfall in most of the case WSSs. One respondent stated that the decrease in rainfall led to deterioration of the quality of water. He gave an example of one case WSS (where there was a decreasing trend of rainfall) where the content of iron had increased from 0.34mg/litre in 2007 to 1.06mg/litre in 2010. He explained that this was the case because when rainwater is not much, concentration of some chemical elements in the raw water increases due to inadequate dilution. This is supported by Benito et al (2010) who state that floods dilute and/or displace poor quality water in the aquifers.

Substantiating "climate change impact - decrease in rainfall" as a root cause: If there was no decrease in rainfall, there would be adequate floods to dilute concentration of chemicals in the water. As such, contents of chemicals in the water would not be much. Therefore, climate change impact - decrease in rainfall was one of the root causes of poor quality raw water.

The reason why the decreasing trend of rainfall could not be reversed

The decreasing trend of rainfall could not be reversed because climate change impacts were irreversible in the short-term as noted by Chen et al (2010).

Proposed tactics for dealing with the challenge of poor quality raw water resulting from decrease in rainfall

a - Monitor the trend of the quality of available raw water (T15) - *details are on page 117*

b - Upgrade existing water supply infrastructure in time (T16)

If the projected trend of the quality of raw water shows that the existing water treatment plant will not be able to treat the water by a particular date, the infrastructure should be upgraded by the projected date. This will ensure that the plant will be able to treat the water of the projected quality.

Upgrading the infrastructure assists to treat water of poor quality as stated by one of the respondents that *"...where the quantity of iron increased, the method of water treatment was changed. In addition to applying coagulant, pre-chlorination was introduced to oxidise the iron"* (Respondent No. 12-12).

c - Develop and use alternative water source (T10) - *details are on page 111*

d - Relocate the affected settlement to a new area (T12) - *details are on page 112*

e - Government should provide financing for DWS systems which are not cost-effective (T13) - *details are on page 112*

4.3.3 Capacity of infrastructure to produce and supply adequate water (CE3)

4.3.3.1 Factors that affected production & supply of adequate water

Capacity of infrastructure to produce and supply adequate water continually was affected by a number of factors in the case WSSs. The factors are contained in the quotations in box 19.

Box 19: Factors that affected continual production and supply of adequate water

> "When quality of raw water gets bad during floods in the rainy season, the treatment plant fails to handle the poor quality raw water, and the plant is stopped thereby affecting the quantity of water produced" (Respondent No. 8-12)
>
> "... the water these days becomes very turbid during the rainy season to the extent that the existing infrastructure cannot treat that poor quality water. As such, the water is channelled back into the river" (Respondent No. 2-12)
>
> "The DWS coverage percentage keeps dwindling on daily basis because while the capacity of the infrastructure is stagnant, the rate of urbanisation is quite high" (Respondent No. 11-10)
>
> "With increase in the population of the water users, the existing tank no longer has adequate capacity" (Respondent No. 14-7)
>
> "This water supply system does not provide water to all the users all the time because water demand has increased over the time" (Respondent No. 22-9)
>
> "The amount of water that we abstract from the source is no longer adequate because of increased water demand due to increased population. The amount of water that we abstract is limited by the capacity of the pipeline" (Respondent No. 22-9)
>
> "The other reason why the existing infrastructure is not able to produce and supply adequate water is that water loss is quite high" (Respondent No. 12-8)

The quotations in box 19 show that the capacity of the infrastructure was not sufficient to produce and supply adequate water continually in some of the case WSSs because:

i. Population had increased beyond the number which was considered in the design of the infrastructure;
ii. Non-domestic activities that used water were more than that considered in the design of the infrastructure;
iii. The existing infrastructure was not able to produce potable water whenever the quality of raw water got bad;
iv. The water demand had grown beyond what the existing infrastructure could produce; and
v. The water losses were high that it was difficult for the existing infrastructure to produce and supply adequate water.

This implies that capacity of infrastructure to produce and supply adequate water continually in the case WSSs was affected by population increase, increase in non-domestic activities that used water, quality of raw water, growth of water demand, and the level of water loss. These factors need to be managed for the capacity of infrastructure to produce and supply adequate water continually to be sustained.

4.3.3.2 Consequence of not managing the factors

The factors that affected capacity of infrastructure to produce and supply adequate water continually were not managed as required in some of the case WSSs as discussed in section 4.3.3.4. The consequence of not managing the factors in the required manner was that there was insufficient capacity to produce and supply adequate water continually (Cq 3). This was the situation in 4 of the 10 case WSSs.

4.3.3.3 Strategy for managing production & supply of adequate water

Ensuring that infrastructure for DWS always has sufficient capacity to produce and supply adequate water for the demand (**S3**)

This strategy is supported by Lockwood (2003) who advises that for DWS services to be sustainable, infrastructure should continue to produce and supply water of sufficient quantity. For this to be achieved, the root causes of insufficient capacity of infrastructure to produce and supply adequate water continually should be addressed. The paragraphs that follow discuss the root causes and the proposed tactics for addressing them:

4.3.3.4 Root causes and how to manage them

This study has found out that there were 7 root causes of insufficient capacity of infrastructure to produce and supply adequate water continually in the case WSSs. The 7 root causes as well as the other 5 factors that affected sustainability of the capacity of the infrastructure to produce and supply adequate water continually in the case WSSs are shown in figure 9, which is an extract from figure 6.

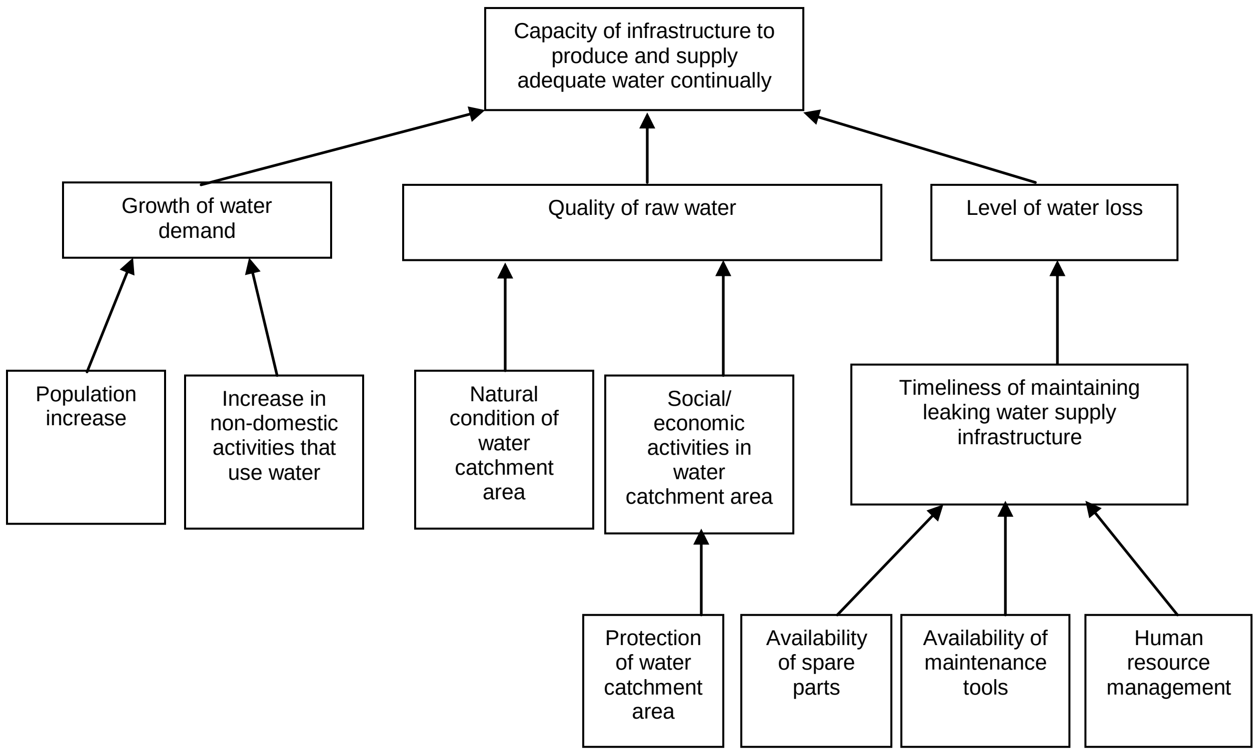


Figure 9: Relationship of the factors that affect production and supply of adequate water

The 7 root causes of insufficient capacity of infrastructure to produce and supply adequate water continually, the reasons why they could not be addressed, and the proposed tactics for managing them are as follows:

1. *Root cause 1 for insufficient capacity of infrastructure to produce and supply adequate water* - Increased population (RC9)

Population growth in a WSS is projected based on the population growth rate for the area served or to be served by the WSS. The population growth rates for the 10 case WSSs between 1987 and 2008 were as shown in table 26.

Table 26: Population growth rates in the case WSSs between 1987 and 2008

Case WSS	Annual population growth rate (%)	
	1987-1998	1999-2008
Chitipa	2.4	3.5
Ighembe	2.5	3.4
Nkhamanga-Lunyina	2.7	3.0
Mzuzu	6.2	4.4
Chintheche	1.9	2.8
Salima	2.5	3.2
Chipoka Town	2.5	3.2
Chipoka Rural	2.5	3.2
Mudi	3.3	2.8
Chiradzulu	1.0	2.1

Source: Malawi National Statistical Office (1998 and 2008)

It will be noted from table 26 that the population growth rates between 1999 and 2008 for 8 of the 10 case WSSs were higher than those that prevailed at the time the WSSs were upgraded (between 1987 and 1998 or earlier). With this, it is not surprising that during the period 1999-2008 the population increased beyond that considered in the design of the infrastructure (between 1987 and 1998 or earlier). Such increase led to the growth of water demand (Butler and Memon, 2006; Lockwood, 2003; Wibowo and Mohamed, 2010) which could not be satisfied with the quantity of water produced and supplied by the existing infrastructure.

Substantiating "increased population" as a root cause: If the population did not increase beyond that considered in the design of the existing infrastructure, the water demand should not have overgrown the capacity of the infrastructure. Talking about one of the case WSSs, one respondent stated that *"with increase in the population of the water users, the existing tank no longer has adequate capacity"* (Respondent No. 14-7). Therefore, increased population was one of the root causes of insufficient capacity of the infrastructure to produce and supply adequate water.

The reasons why the quantity of water supplied could not satisfy the demand of the increased population

The quantity of water supplied did not satisfy the demand of the increased population because:

i. Analysis for assessing if the existing infrastructure would produce and supply enough water for the projected demand was not conducted; and
ii. Upgrading works were not carried out on time.

Proposed tactics for satisfying water demand for increased population

The major direct solution to deal with population that increases beyond the projected number is birth control (Meadows et al, 2004). However, the responsibility of birth control in Malawi lies with the Ministry of Health. It would not be easy for DWS service providers to participate in birth control because they do not have necessary expertise. As such, it is proposed that DWS service providers should look at this problem from the perspective of DWS for which they have expertise.

a - Monitor the trend of the water demand growth (T17)

DWS service providers should establish trends of water demand growth and determine the date when the existing infrastructure will not be able to produce and supply enough water for the projected demand. This would assist in planning the upgrading works of the infrastructure.

b - Upgrade existing water supply infrastructure in time (T16)

Existing water supply infrastructure should be upgraded before the date when the infrastructure will not be able to produce and supply enough and potable water for the projected demand. This is supported by Banerjee et al (2008) and Man et al (2011) who state that infrastructure should be upgraded and extended in order to satisfy water demand of the rapid population growth. Upgrading of infrastructure also enhances its capacity to produce safe water. One respondent stated that *“baffle flocculators were introduced at the water treatment plant when it was noted that the existing infrastructure was not able to produce safe water from the raw water whose quality had deteriorated. Positive results were realised”* (Respondent No. 12-12).

2. *Root cause 2 for insufficient capacity of infrastructure to produce and supply adequate water* - Increased non-domestic activities that use water (RC10)

Some respondents indicated that there were increased non-domestic activities that used water compared to what were considered in the design of the infrastructure. These included industrial and commercial activities. The increased non-domestic activities led to the growth in water demand (Butler and Memon, 2006; Wibowo and Mohamed, 2010) which could not be satisfied with the quantity of water produced and supplied by the existing infrastructure in 6 of the 10 case WSSs.

Substantiating "increased non-domestic activities that used water" as a root cause: If the non-domestic activities that used water did not increase beyond that considered in the design of the existing infrastructure, the water demand should not have overgrown the capacity of the infrastructure. Therefore, increased non-domestic activities that used water were one of the root causes of insufficient capacity of the infrastructure to produce and supply adequate water.

The reasons why the quantity of water supplied could not satisfy the demand of the increased number of non-domestic activities that used water

The quantity of water supplied did not satisfy the demand of the increased number of non-domestic activities that used water because:

i. Analysis for assessing if the existing infrastructure would produce and supply enough water for the projected demand was not conducted; and
ii. Upgrading works were not carried out on time.

Proposed tactics for satisfying water demand for increased number of non-domestic activities that used water

a - Monitor the trend of the water demand growth (T17) - *details are on page 124*

b - Upgrade existing water supply infrastructure in time (T16) - *details are on page 124*

3. *Root cause 3 for insufficient capacity of infrastructure to produce and supply adequate water -* Poor natural condition of water catchment areas (RC7)

As indicated in section 4.3.2, poor natural condition of a water catchment area leads to poor quality raw water. In one of the case WSSs, the existing facilities could not treat raw water from a catchment area with poor natural condition because the quality of the water had deteriorated beyond a level which could be treated by the existing infrastructure. When the water, which was not fully treated, flowed through the pipes, the pipes got clogged with calcium concentrates. Once that happened, the infrastructure failed to supply water to the users thereby affecting the quantity of water supplied by the infrastructure.

Substantiating "poor natural condition of water catchment areas" as a root cause: If the natural condition of the water catchment area was not poor, the quality of raw water would not deteriorate beyond a level which could be treated by the existing infrastructure, to the extent that the infrastructure stopped supplying water. Therefore, poor natural condition of water catchment areas was one of the root causes of insufficient capacity of the infrastructure to supply adequate water.

The reasons why the quantity of water produced from catchment areas with poor natural condition was not adequate

The quantity of water produced from catchment areas with poor natural condition was not adequate because:

i. Analysis for assessing if the existing infrastructure would be able to treat raw water of deteriorating quality in the future was not conducted
ii. Upgrading works were not carried out on time

Proposed tactics for infrastructure to produce and supply adequate treated water from raw water abstracted from catchment areas with poor natural condition

a - Monitor the trend of the quality of raw water (T15) - *details are on page 117*

b - Upgrade existing water supply infrastructure in time (T16) - *details are on page 124*

c - Develop and use alternative/additional water source (T10) - *details are on page 111*

d - Relocate the affected settlement to a new area (T12) - *details are on page 112*

e - Government should provide financing for DWS systems which are not cost-effective (T13) - *details are on page 112*

4. *Root cause 4 for insufficient capacity to produce and supply adequate water* - Failure to protect water catchment areas (RC1)

As indicated in section 4.3.1, failure to protect water catchment areas allows people to be free to carry out social/economic activities in the water catchment areas. This leads to deterioration of the quality of raw water to a level which cannot be treated by the existing plant. In one case WSS, the quality of water got so bad during the rainy season to the point that the plant was stopped, and the water allowed to flow back into the river until the quality of the water improved. This resulted in production of inadequate quantity of water.

Substantiating "failure to protect water catchment areas" as a root cause: If the water catchment areas were protected, social/economic activities could not have taken place in the catchment areas. As such, the quality of raw water would not deteriorate beyond a level which could be treated by the existing plant (Braune and Xu, 2010), and that the plant had to be stopped. Therefore, failure to protect water catchment areas was one of the root causes of insufficient capacity of the infrastructure to produce adequate water.

The reasons why water catchment areas could not be protected

The water catchment areas in 4 of the 10 case WSSs could not be protected because:

i. The catchment areas were not declared protected areas in the manner required by law; and
ii. There was no mechanism for enforcing by-laws for protecting catchment areas.

Proposed tactics for ensuring protection of water catchment areas

a - Declare water catchment area as a protected area (T1) - *details are on page 102*

b - Manage water catchment area (T2) - *details are on page 102*

5. *Root cause 5 for insufficient capacity of infrastructure to produce and supply adequate water* - Unavailability of spare parts (RC3); and
6. *Root cause 6 for insufficient capacity of infrastructure to produce and supply adequate water* - Unavailability of appropriate maintenance tools (RC4)

As indicated in section 4.3.1, spare parts and appropriate maintenance tools were not available most of the time in the case WSSs. This led to delayed maintenance of leaking water supply facilities, among other challenges. This contributed to high water losses which ranged from 20% to 47% (table 23). Water loss requires that the infrastructure upstream of the point where the water is lost should be big enough to produce and supply the quantity of water which is eventually used plus the water loss. This means that the higher the water losses, the bigger the capacity should the infrastructure have, otherwise the infrastructure will not have sufficient capacity to produce and supply adequate water.

Substantiating "unavailability of spare parts, and unavailability of appropriate maintenance tools" as root causes: If spare parts and appropriate maintenance tools were available, maintenance works for the leaking facilities would have been carried out on time, and water losses would not be high. If the water losses were not high, the capacity of the infrastructure should have been sufficient to produce and supply adequate water. Therefore, unavailability of spare parts and appropriate maintenance tools were some of the root causes of insufficient capacity of infrastructure to produce and supply adequate water.

The reason why spare parts and appropriate maintenance tools were not available

Spare parts and appropriate maintenance tools were not available at the time they were required because it took long for these items to be purchased. This was the case because purchase of these items was not prioritised.

Proposed tactics for ensuring availability on time of spare parts and appropriate maintenance tools

a - Prepare a list of required spare parts and appropriate maintenance tools (T5) - *details are on page 106*

b - Prioritise and enforce purchase of spare parts and appropriate maintenance tools (T6) - *details are on page 106*

7. *Root cause 7 for insufficient capacity of infrastructure to produce and supply adequate water* - Number of personnel that does not consider the amount of work to be carried out (RC5)

As discussed in section 4.3.1, the number of personnel allocated to carry out maintenance works was not adequate in some of the case WSSs. As such, there was delayed implementation of maintenance works. Consequently, a lot of water was lost. The high water loss rendered the capacity of the infrastructure insufficient to produce and supply adequate water for the demand.

Substantiating "Number of personnel that does not consider amount of work to be carried out" as a root cause: If the number of personnel allocated to carry out maintenance works was adequate, maintenance works would be carried out on time, and not much water would be lost. Hence, the capacity of the existing infrastructure should have been sufficient to produce and supply adequate water. Therefore, number of personnel that does not consider the amount of work to be carried out was one of the root causes of insufficient capacity of infrastructure to produce and supply adequate water.

The reason why the number of personnel could not match the amount of work carried out

The number of personnel could not match the amount of work carried out because either the total number of staff was not adequate or the staff members were not allocated equitably amongst the sections of the DWS institutions.

Proposed tactic for matching the number of personnel with the amount of work to be carried out

a - The number of staff should be based on the amount of work to be carried out (T7) - *details are on page 108*

4.3.4 Capacity of infrastructure to produce safe water continually (CE4)

4.3.4.1 Factors that affected capacity to produce safe water

Capacity of infrastructure to produce safe water continually in the case WSSs was affected by the factors mentioned in the quotations in box 20.

Box 20: Factors that affected capacity to produce safe water continually

> "The water treatment plant is not able to treat the bad quality raw water because it was designed on the basis of good quality raw water" (Respondent No. 1-1)
>
> "In order to satisfy the demand, much more water is forced through a few filters which results in production of water with higher than specified turbidity ... We are, therefore, in a process of taking out part of the supply area from this water supply system...We will revive the abandoned water supply system situated in that area so that it can serve the part that will be removed from this water supply system ...." (Respondent No. 12-12)
>
> "High water losses lead to increased amount of the required treated water. In order to produce such amount of water, a lot of raw water is forced through the treatment plant within a short time with the consequence that the produced water is of substandard quality" (Respondent No. 12-11)

The quotations in box 20 indicate that the capacity of the infrastructure was not sufficient to produce safe water continually in some of the case WSSs because:

i. The existing infrastructure was not able to produce potable water whenever the quality of raw water got bad;
ii. The water demand had grown beyond what the existing infrastructure could produce (because of population increase, and increase in non-domestic activities that used water), and at the same time maintain the required quality of treated water; and
iii. The water losses were high that it was difficult for the existing infrastructure to produce adequate, and at the same time safe water.

This implies that capacity of infrastructure to produce safe water continually in the case WSSs was affected by the quality of raw water, growth of water demand, and the level of water loss. These factors need to be managed in order to sustain the capacity of infrastructure to produce safe water continually.

4.3.4.2 Consequence of not managing the factors

The factors that affected the capacity of infrastructure to produce safe water continually were not managed as required in some of the case WSSs as discussed in section 4.3.4.4. The consequence of not managing the factors in the required manner was that there was insufficient capacity of infrastructure to produce safe water continually (Cq 4). This was the situation in 3 of the 10 case WSSs.

4.3.4.3 Strategy for managing capacity to produce safe water

Ensuring that infrastructure for DWS always has sufficient capacity to produce water which is safe for human consumption (**S4**)

This strategy is supported by Lockwood (2003) who states that for DWS services to be sustainable, infrastructure should continue to produce water which is safe for human consumption. For this to be achieved, the root causes of insufficient capacity of infrastructure to produce safe water continually should be addressed. The paragraphs that follow discuss the root causes and the proposed tactics for addressing them:

4.3.4.4 Root causes and how to manage them

This study has found out that there were 7 root causes of insufficient capacity of infrastructure to produce safe water continually in the case WSSs. The 7 root causes as well as the other 5 factors that affected the capacity of the infrastructure to produce safe water continually in the case WSSs are in figure 10, which is an extract from figure 6.

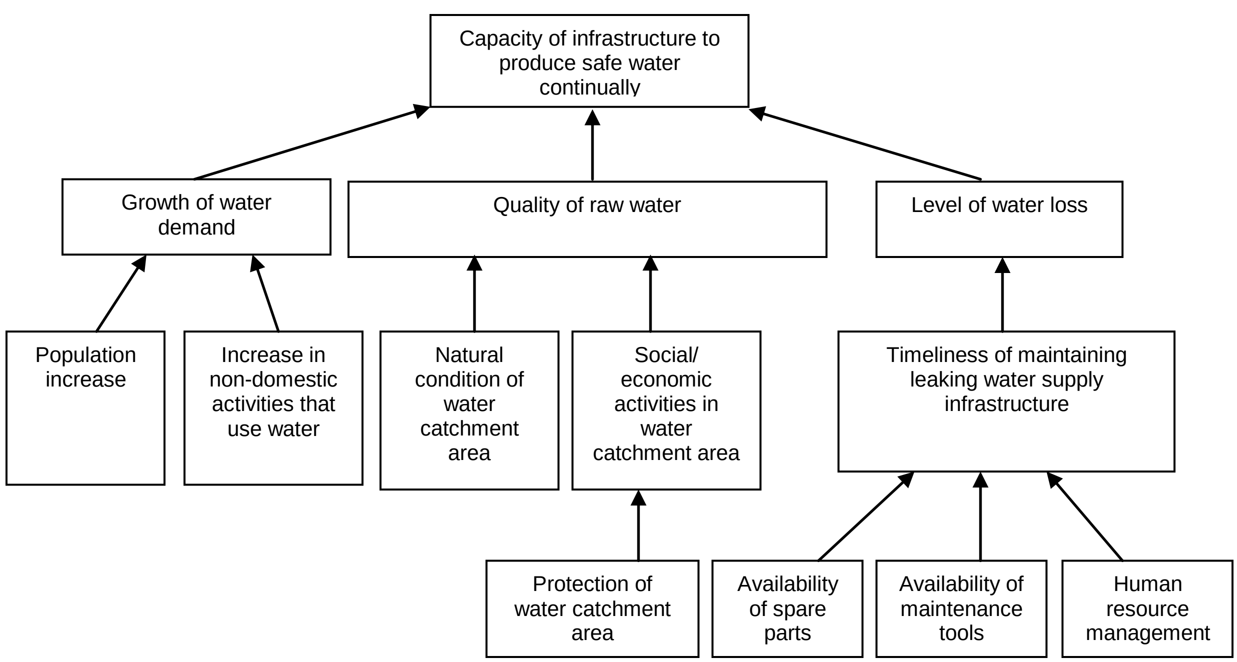


Figure 10: Relationship of the factors that affect production of safe water

The 7 root causes of insufficient capacity of infrastructure to produce safe water continually, the reasons why they could not be addressed, and the proposed tactics for managing them are as follows:

1. *Root cause 1 for insufficient capacity of infrastructure to produce safe water continually* - Increased population (RC9)

The population increased beyond that considered in the design of the infrastructure in 8 of the 10 case WSSs as shown in section 4.3.3. The increase in the population led to the increase in water demand (Butler and Memon, 2006; Lockwood, 2003; Wibowo and Mohamed, 2010) which could not be satisfied with the quantity of water produced by the existing infrastructure. The plant was, therefore, forced to produce more water. One interviewee stated that more water had to be forced into a few filters in order to satisfy the demand. The output was water of substandard quality i.e. with higher than specified turbidity.

Substantiating "increased population" as a root cause: If the population did not increase beyond the assumed number, the water demand should not have reached a point whereby the water produced to satisfy the demand was too much for the existing infrastructure to produce safe water. Therefore, increased population was one of the root causes of insufficient capacity of the infrastructure to produce safe water.

The reasons why the quantity of water supplied could not satisfy the demand of the increased population

The quantity of water supplied did not satisfy the demand of the increased population because:

i. Analysis for assessing if the existing infrastructure would produce and supply enough water for the projected demand was not conducted; and
ii. Upgrading works were not carried out on time.

Proposed tactics for satisfying water demand for increased population

a - Monitor the trend of the water demand growth (T17) - *details are on page 124*

b - Upgrade existing water supply infrastructure in time (T16) - *details are on page 124*

2. *Root cause 2 for insufficient capacity of infrastructure to produce safe water continually* - Increased non-domestic activities that use water (RC10)

In 6 of the 10 case WSSs, non-domestic activities that used water increased beyond that considered in the design of the infrastructure. As it was the case with the increased population, the increase in the non-domestic activities that used water led to the growth in water demand (Butler and Memon, 2006; Wibowo and Mohamed, 2010) which could not be satisfied with the quantity of water produced by the existing infrastructure. As such, the plant was forced to produce more water. While indeed more water was produced, the produced water was of poor quality.

Substantiating "increased non-domestic activities that used water" as a root cause: If the non-domestic activities that used water did not increase beyond that considered in the design of the infrastructure, the water demand should not have grown beyond the point above which the water produced by the existing infrastructure was not safe. Therefore, increased non-domestic activities that used water were one of the root causes of insufficient capacity of the infrastructure to produce safe water.

The reasons why the quantity of water supplied could not satisfy the demand of the increased number of non-domestic activities that used water

The quantity of water supplied did not satisfy the demand of the increased number of non-domestic activities that used water because:

i. Analysis for assessing if the existing infrastructure would produce and supply enough water for the projected demand was not conducted; and
ii. Upgrading works were not carried out on time.

Proposed tactics for satisfying water demand for increased number of non-domestic activities that used water

a - Monitor the trend of the water demand growth (T17) - *details are on page 124*

b - Upgrade existing water supply infrastructure in time (T16) - *details are on page 124*

3. *Root cause 3 for insufficient capacity of infrastructure to produce safe water continually -* Poor natural condition of water catchment areas (RC7)

As indicated in section 4.3.2, poor natural condition of water catchment areas leads to poor quality raw water. In one of the case WSSs, the existing facilities could not treat raw water from a catchment area with poor natural condition because the quality of the water had deteriorated beyond a level which could be treated by the existing infrastructure.

Substantiating "poor natural condition of water catchment areas" as a root cause: If the natural condition of the water catchment area would not lead to poor quality raw water, the existing infrastructure would produce safe water. Therefore, poor natural condition of the water catchment area was one of the root causes of insufficient capacity of the infrastructure to produce safe water.

The reasons why the water produced from catchment areas with poor natural condition was not safe for human consumption

The water produced from catchment areas with poor natural condition was not safe for human consumption because:

i. Analysis for assessing if the existing infrastructure would continue producing safe water from the water abstracted from the catchment areas with poor natural condition was not conducted; and
ii. Upgrading works were not carried out on time

Proposed tactics for the infrastructure to produce safe water from the water abstracted from catchment areas with poor natural condition

a - Monitor the trend of the quality of raw water (T15) - *details are on page 117*

b - Upgrade existing water supply infrastructure in time (T16) - *details are on page 124*

c - Develop and use alternative/additional water source (T10) - *details are on page 111*

d - Relocate the affected settlement to a new area (T12) - *details are on page 112*

e - Government should provide financing for DWS systems which are not cost-effective (T13) - *details are on page 112*

4. *Root cause 4 for insufficient capacity of infrastructure to produce safe water continually -* Failure to protect water catchment areas (RC1)

As indicated in section 4.3.1, failure to protect water catchment areas allows people to be free to carry out social/economic activities in the water catchment areas. This leads to the deterioration of the quality of raw water. The quality of raw water deteriorated in 4 of the 6 case WSSs where the catchment areas were not protected. The poor quality raw water could not be treated by the existing infrastructure as the infrastructure was designed based on good quality raw water. As such, the water that was produced was of substandard quality.

Substantiating "failure to protect water catchment areas" as a root cause: If the water catchment areas were protected, social/economic activities would not have taken place in the catchment areas. As such, quality of raw water would not be poor (Braune and Xu, 2010). In that case, the existing infrastructure would produce safe water. Therefore, failure to protect water catchment area was one of the root causes of insufficient capacity of the infrastructure to produce safe water.

The reasons why water catchment areas could not be protected

The water catchment areas in 4 of the 10 case WSSs could not be protected because:

i. The catchment areas were not declared protected areas in the manner required by law; and
ii. There was no mechanism for enforcing by-laws for protecting catchment areas.

Proposed tactics for ensuring protection of water catchment areas

a - Declare water catchment area as a protected area (T1) - *details are on page 102*

b - Manage water catchment area (T2) - *details are on page 102*

5. *Root cause 5 for insufficient capacity of infrastructure to produce safe water continually* - Unavailability of spare parts (RC3); and
6. *Root cause 6 for insufficient capacity of infrastructure to produce safe water continually* - Unavailability of appropriate maintenance tools (RC4)

As discussed in section 4.3.3, spare parts and appropriate maintenance tools were not available most of the time in the case WSSs. This led to delayed maintenance of leaking water supply facilities. This contributed to high water losses which ranged from 20% to 47% (table 23). Water loss requires that more water should be produced. In this regard, the capacity of the water treatment plant has to be big enough to cover the loss otherwise raw water is rushed through the under-capacity plant, and the produced water is of substandard quality.

Substantiating "unavailability of spare parts, and unavailability of appropriate maintenance tools" as a root cause: If spare parts and appropriate maintenance tools were available, maintenance works for the leaking facilities would have been carried out on time, and water losses would not be high. If the water losses were not high, the capacity of the water treatment plant should have been sufficient to produce safe water. Therefore, unavailability of spare parts and appropriate maintenance tools were some of the root causes of insufficient capacity of the infrastructure to produce safe water.

The reason why spare parts and appropriate maintenance tools were not available

Spare parts and appropriate maintenance tools were not available at the time they were required because it took long for these items to be purchased. This was the case because purchase of these items was not prioritised.

Proposed tactics for ensuring availability on time of spare parts and appropriate maintenance tools

a - Prepare a list of required spare parts and appropriate maintenance tools (T5) - *details are on page 106*

b - Prioritise and enforce purchase of spare parts and appropriate maintenance tools (T6) - *details are on page 106*

7. *Root cause 7 for insufficient capacity of infrastructure to produce safe water continually* - Number of personnel that does not consider the amount of work to be carried out (RC5)

As discussed in section 4.3.1, the number of personnel allocated to carry out maintenance works was not adequate in some of the case WSSs. As a result, maintenance works were not carried out on time. Consequently, a lot of water was lost. With the high water loss, the water treatment plant was supposed to treat more water than the water demand in order to compensate for the lost water. The existing infrastructure was not able to do this because the water loss was higher than assumed. The maximum water loss that is considered in most designs for water supply infrastructure in Malawi is 25% (Metaferia Consultants, 2008; Sogreah Consultants, 2009). However, as noted from table 23, water losses in 5 of the 7 case WSSs included in the table were higher than 25%. Therefore, in an effort to satisfy the demand despite high water loss, more water was pushed through the plant with the output being substandard water.

Substantiating "Number of personnel that does not consider amount of work to be carried out" as a root cause: If the number of personnel allocated to carry out maintenance works was adequate, maintenance works would be carried out on time, and not much water would be lost. As such, the quantity of water required would be within the capacity of the existing infrastructure, hence the water produced would be of acceptable quality. Therefore, number of personnel that does not consider the amount of work to be carried out was one of the root causes of insufficient capacity of infrastructure to produce safe water.

The reason why the number of personnel could not match the amount of work carried out

The number of personnel could not match the amount of work carried out because either the total number of staff was not adequate or the staff members were not allocated equitably amongst the sections of the DWS institutions.

Proposed tactic for matching the number of personnel with the amount of work to be carried out

a - The number of staff should be based on the amount of work to be carried out (T7) - *details are on page 108*

4.3.5 Continual functioning of infrastructure as required at design stage (CE5)

4.3.5.1 Factors that affected continuity of infrastructure to function

Continuity of infrastructure to function as required at the design stage in the case WSSs was affected by the factors mentioned in the quotations in box 21.

Box 21: Factors that affected continual functioning of infrastructure

> "The reason why the pumps break down so often is that preventative maintenance is not carried out on schedule" (Respondent No. 11-4)
>
> "Proper maintenance is not carried out but improvisations…" (Respondent No. 8-8)
>
> "Maintenance that is carried out is for the sake of keeping going. Proper maintenance is not carried out …" (Respondent No. 11-10)
>
> "Raw water pumps for this water supply system break down frequently because impellers wear out often because the raw water contains small sand particles" (Respondent No. 11-4)
>
> "This water supply system was commissioned in 1953. The pipes that were installed that time have not been replaced, rather the works that have been implemented over the years were for expanding the system. Such pipes burst a lot because of aging as well as high pressures which are exerted to pump water to high-lying areas where people are settling these days" (Respondent No. 1-1)
>
> "The main challenge that disturbs supply of water is unavailability of materials for maintenance" (Respondent No. 21-7)
>
> "The water supply system is no longer providing water to the users because materials for maintenance and cleaning of the tank are not available" (Respondent No. 14-7)
>
> "This water supply system does not provide water to all the users all the time because there are water leakages on the pipelines which have not been repaired despite being there for a long time. This was due to inadequate staff. There was only one plumber who doubled as a driver" (Respondent No. 22-9)

“There was a time when pipelines were vandalised a lot by the people who lived along the pipelines but were not supplied with the water.” (Respondent No. 15-9)

“Some people vandalise our infrastructure like pipes to have access to the water” (Respondent No. 1-1)

“For over two years, we have not been able to train and equip our divers because of cash-flow problems. Training of the divers is quite low on the priority list with the little cash that we collect” (Respondent No. 2-4)

“The salaries that we receive are not satisfactory because the amounts are based on the little income that is generated from this water supply system” (Respondent No. 22-9)

“In most cases, volunteers do not maintain breakdowns quickly. This is the case because they need time to work on activities from which they earn a living” (Respondent No. 21-7)

“The other system is defunct because the intake structure was washed away by extreme flood which occurred” (Respondent No. 21-3)

“When *mwera* winds blow, the water intake pipeline gets choked because the water is mixed with silts and sand” (Respondent No. 2-4)

“The contractor installed pipelines at shallow depths into the ground. Consequently, those pipelines got broken easily even by ploughing the soil on top of the pipelines” (Respondent No. 29-7)

“Pipes that break frequently are those in shallow trenches and sometimes not backfilled” (Respondent No. 23)

“Every component in a water supply infrastructure has a life span. The components have to be replaced once the life span expires without reaching the extent whereby the component breaks down...This is not done because of unavailability of adequate financing” (Respondent No. 29-11)

“Faults are not identified at early stage by the operative staff because they do not have requisite skills. As such, faults are only identified after breaking down of infrastructure. The operative staff are not trained adequately because there are no appropriate training institutions in the country” (Respondent No. 12-11)

The quotations in box 21 show that in some of the case WSSs the infrastructure did not function continually in a manner required at the design stage because:

i. The infrastructure was vandalised;
ii. There was increased rate and extent of infrastructure (e.g. pipes) breakdowns because the infrastructure had been used beyond its useful life time without refurbishment;
iii. The personnel involved in the maintenance work were not properly trained;
iv. The personnel involved in the maintenance work were not motivated mainly because of low salaries;

v. Maintenance was not carried out on time and in the required manner;
vi. Materials for maintenance work were not available;
vii. The technology used was not appropriate for the environment in which it worked e.g. pumps used were not suitable for silty water, and the intake pipeline was not properly secured to avoid entry of silts and sand.
viii. The amount of work did not match with the number of people deployed to carry out some works;
ix. Some facilities had been washed away because of extreme floods that occurred;
x. Quality of constructed infrastructure was poor due to poor performance by contractors;
xi. Preventative maintenance was not carried out in most cases; and
xii. Problems were not identified in time due to lack of requisite knowledge in the deployed personnel.

This implies that continuity of infrastructure to function as required at the design stage in the case WSSs was affected by the age of the infrastructure, vandalism, involvement of untrained and unmotivated personnel, lack of preventative maintenance, lack of troubleshooting, rate and extent of breakdown, supply of spare parts and maintenance tools, capacity to carry out proper maintenance of infrastructure, type of technology used, human resource management, quality of infrastructure, and climate change impacts. These factors need to be managed for continual functioning of infrastructure, as required at the design stage, to be sustained.

4.3.5.2 Consequence of not managing the factors

The factors that affected continual functioning of infrastructure were not managed as required in some of the case WSSs as discussed in section 4.3.5.4. The consequence of not managing the factors in the required manner was prolonged breakdown of the infrastructure (Cq 5). Some breakdowns took long to maintain in all the 10 case WSSs.

4.3.5.3 Strategy for managing continual functioning of infrastructure

Ensuring that broken down infrastructure is maintained within a short time (**S5**)

This strategy is supported by Carter et al (1999) who state that infrastructure should function continually if DWS services are to be sustained. For the infrastructure to function continually, the root causes of prolonged breakdowns should be addressed. The paragraphs that follow discuss the root causes and the proposed tactics for addressing them:

4.3.5.4 Root causes and how to manage them

This study has found out that there were 11 root causes of prolonged breakdown of infrastructure in the case WSSs. The 11 root causes as well as the other 12 factors that affected continual functioning of the infrastructure as required at the design stage are shown in figure 11, which is an extract from figure 6.

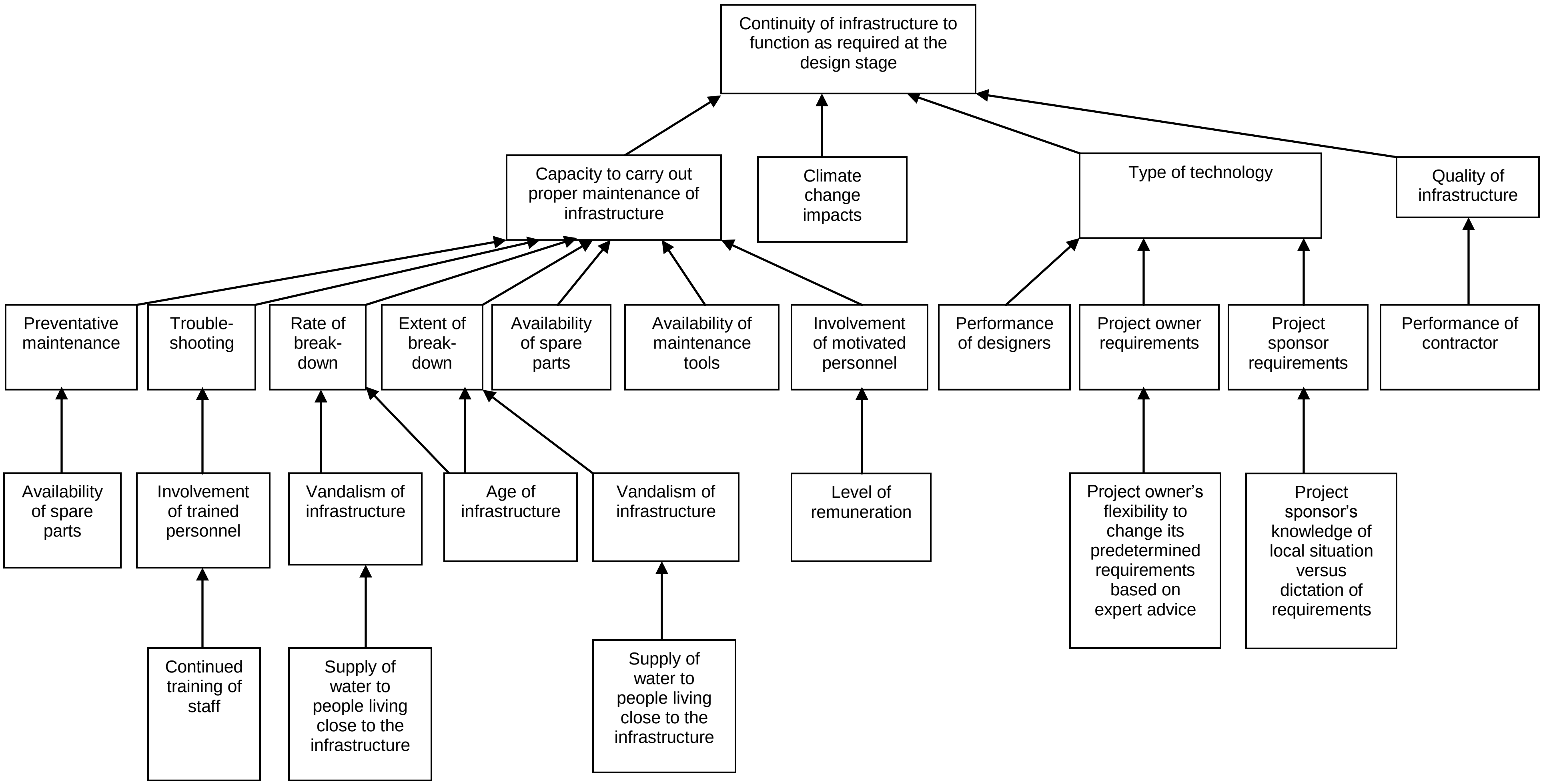


Figure 11: Relationship of the factors that affect continual functioning of infrastructure

The 11 root causes of prolonged breakdown of infrastructure, the reasons why they could not be addressed, and the proposed tactics for managing them are as follows:

1. *Root cause 1 of prolonged breakdown of infrastructure* - Unavailability of spare parts (RC3); and
2. *Root cause 2 of prolonged breakdown of infrastructure* - Unavailability of appropriate maintenance tools

As indicated in section 4.3.1, spare parts and appropriate maintenance tools were not available most of the time in all the 10 case WSSs. Consequently, preventative maintenance was not carried out on time and in the required manner. As a result, certain parts of the infrastructure broke down, and the infrastructure stopped working. Carter et al (1999) state that sustainability of DWS services fails if water supply infrastructure is not maintained. Sara and Katz (1998) advise that preventative maintenance is required to keep a water supply system functioning over time.

Having broken down, the infrastructure needed to be maintained. Unavailability of the required spare parts and appropriate maintenance tools resulted in delayed maintenance. This was the case because time was spent looking for spare parts or improvising them and/or taking a longer route of maintaining the infrastructure due to unavailability of appropriate maintenance tools.

In some instances, delayed maintenance of certain parts led to breakdown of other parts *("...If a component breaks down, other components of the infrastructure may be damaged..." (Respondent No. 29)*), and major breakdowns occurred. Maintenance of many parts required many spare parts, while maintenance of major breakdowns needed to be carried out by experts. Organisation of many parts and experts (whose base was at the head offices, far from the WSSs) took long and led to delayed maintenance of the infrastructure.

Substantiating "unavailability of spare parts, and unavailability of appropriate maintenance tools" as root causes: If spare parts and appropriate maintenance tools were available, the affected parts would be maintained within a short time (Sara and Katz, 1998) hence there would be no prolonged breakdown of the infrastructure. Therefore, unavailability of spare parts and appropriate maintenance tools were some of the root causes of prolonged breakdown of infrastructure. This is supported by RWSN (2010) who state that unavailability of spare parts is a cause of prolonged breakdown of infrastructure.

The reason why spare parts and appropriate maintenance tools were not available

Spare parts and appropriate maintenance tools were not available at the time they were required because it took long for these items to be purchased. This was the case because purchase of these items was not prioritised.

Proposed tactics for ensuring availability on time of spare parts and appropriate maintenance tools

a - Prepare a list of required spare parts and appropriate maintenance tools (T5) - *details are on page 106*

b - Prioritise and enforce purchase of spare parts and appropriate maintenance tools (T6) - *details are on page 106*

3. *Root cause 3 of prolonged breakdown of infrastructure* - Limited continued training of staff (RC11)

There was limited continued training of staff in all the 10 case WSSs. Table 27 shows the numbers of personnel who had been trained in the case WSSs in the last one year prior to this research.

Table 27: Numbers of staff in the case WSSs trained in the year 2013/2014

Case WSS Number*	Personnel trained	Total number of personnel
1	1	16
2	24	136
3	1	10
4	3	18
5	72	463
6	1	6
7	0	8
8	0	1
9	0	12
Total	102	670

Note:

* These numbers are used to distinguish one case WSS from another and not to identify the systems. The numbers shown for the personnel trained are for 9 case WSSs because there were no workers at one of the case WSSs because it was no longer operational.

Source: Records kept by the Scheme Managers

Table 27 shows that only about 15% of the staff members had been trained in the last one year prior to this research. This means that it would take 7 years on average for each one of the staff members to be trained, by which time there would be new developments in their areas of expertise.

The situation was worse in 3 of the 10 case WSSs where nobody was trained in the year. Two of the 3 case WSSs were where the people who carried out maintenance works were volunteers from the villages. The volunteers underwent basic training at the beginning, and there was no follow-up training for them. Baumann and Danert (2008) came up with similar finding in their study in Malawi. With this situation (lack of continued and follow-up training), the personnel did not have the requisite knowledge to identify and address real problems in time, especially for new technologies (Lockwood, 2003).

The challenge with failure to identify and address the real problems in time is that other parts of the infrastructure get damaged or the problem becomes complex. One respondent stated that a pump stopped running because the bearings had worn out completely. The stopping of the pump to function resulted in the whole infrastructure not being able to supply water. This could not have happened if the plant operator had undergone follow-up training. Follow-up training for plant operators normally include a reminder on how the sound from a pump in a perfect order should be. Therefore, if the plant operator in question had undergone the follow-up training, he would have known that something was wrong with the pump, by simply listening to the sound of the pump. An investigation would then be done to identify and address the problem. Replacing of bearings would take a short time; otherwise without identifying and addressing the problem in time, other parts of the pump got damaged too. Maintenance of many parts took long resulting in prolonged breakdown of the infrastructure. The respondents said a number of staff members failed to identify problems in time because they were not up-to-date with new technologies.

Substantiating "limited continued training of staff" as a root cause: If there was continued training of staff, the personnel would have been up-to-date with new technologies. In that case, identification and addressing of real problems could be done in time (Morita-Lou and Waters, 2008). If the real problems were identified and addressed in time, there would be no prolonged breakdown of the infrastructure. This would be the case because only a few parts would have broken down, and the breakdowns would not be major to require experts from head office. Therefore, limited continued training of staff was one of the root causes of prolonged breakdown of infrastructure.

The reason why the challenge of limited continued training of staff could not be resolved

The challenge of limited continued training of staff could not be resolved because:

i. Only a few staff members were a priority to undergo training
ii. There was no appropriate training institution in the country for operative staff

Proposed tactics for ensuring continued training of staff

a - Prepare a training schedule for all staff members (T18)

A schedule showing the dates when each of the staff members will be trained should be prepared. The schedule should be such that each staff member should be trained as soon as there have been new developments in their areas of expertise. This is important as in the words of one respondent *"We do not have capacity problems with our staff because they are trained on the job as well as at training institution*s" (Respondent No. 3-11). This is supported by Morita-Lou and Waters (2008) who state that for maintenance to be carried out properly, maintenance personnel should have expertise to do their work.

For the areas of expertise where it takes time to have new developments, staff members should undergo refresher courses at reasonable intervals. The intervals should be such that the staff do not forget what they learnt in the previous training. Otherwise, the situation at the time of the study, whereby in one case, a staff member worked for one of the participating organisations for 11 years but never underwent any refresher training, would make staff members to forget even the basics of their area of expertise.

To ensure that some staff members do not undergo training quite often on the expense of others, the training schedule should be reviewed and approved by people who do not have vested interest. These could be officials from the regulator of DWS services.

b - Implement training schedule (T19)

The approved training schedule should be implemented. RWSN (2010) states that one way of ensuring sustainability of DWS services is follow-up training for staff. The payment officer should be tasked to ensure that payments for training are prioritised. One respondent said if certain staff members do not undergo training quite often, as it was the case, the budgetary allocations would be adequate for everyone.

c - Lobby training institutions in the country to introduce courses for staff working in water utilities (T20)

DWS service providers should lobby the training institutions in the country to introduce courses for staff working in water utilities. If the courses will be taught at the local training institutions, the courses will be cheaper hence more staff members will be trained.

4. *Root cause 4 of prolonged breakdown of infrastructure* - Low remuneration (RC12)

Salaries given to staff members in one of the 7 case WSSs (where salaries were paid) were very low, and there were no salaries at all given to the people working in the other three case WSSs. The monthly salaries given to some of the staff members in the case WSS where the salaries were low and the average for the other six case WSSs are shown in table 28.

Table 28: Monthly salaries in the case WSSs

Position	Salaries	
	For one of the case WSSs (MK)	Average for 6 other case WSSs (MK)
Scheme Manager	50,000	137,000
Plumber	30,000	87,000
Driver	18,000	47,000
Meter Reader	12,000	47,000
Office Assistant	7,000	47,000
Total	117,000	365,000

Source: Records kept by the Scheme Managers and Human Resources Departments

Table 28 shows that, on average, monthly salaries paid to staff members in one of the case WSSs were about one-third of the average salaries paid to staff members in the other 6 case WSSs. In addition, the personnel that performed maintenance works in the other 3 case WSSs were volunteers who were not paid any salaries but only honoraria once in a while. The consequence of low remuneration or not paying salaries to the volunteers is that it takes long for breakdowns to be maintained. This is the case because there is not much to motivate the workers to carry out the maintenance works on time. While the reasons for motivation are subjective (Dorman and Gaudiano, 1994), the respondents felt that amounts of salaries was a major factor that affected motivation of staff in the case WSSs. Some respondents indicated that pipe breakdowns could take up to 2 days to be maintained after being reported although personnel, materials and equipment were sometimes available. As regards volunteers, one interviewee stated that they needed time to work on other activities from which they earned a living, hence their absence from maintenance works of DWS infrastructure. Carter et al (1999) state that voluntary roles are unlikely to be sustainable in the long term.

The result of the unmotivated personnel not maintaining certain parts of the infrastructure on time was prolonged breakdown of the infrastructure, which affected water supply.

Substantiating “low remuneration” as a root cause: If the remuneration was not low and/or all the people maintaining the infrastructure received salaries (there were no unpaid volunteers), the personnel would have been motivated. If the personnel were motivated, maintenance of infrastructure would be carried out on time hence the breakdowns would not be prolonged. Therefore, low remuneration was one of the root causes of prolonged breakdown of infrastructure.

The reason why the remuneration could not be increased

The remuneration could not be increased because the generated revenue was not much in the affected case WSS.

Proposed tactic for motivating personnel

a - Remuneration should not be substantially less than that offered by other water supply utilities in the country (T21)

Each DWS service provider should ensure that its employees do not receive salaries which are substantially less than that received by employees of other water supply utilities in the country. This is important to ensure that the staff members are motivated and work with dedication. Otherwise as stated by one respondent, the staff members become de-motivated and may end up resigning. If the staff members resign, the affected DWS service provider may only remain with staff members who are not well-qualified and/or do not have adequate experience. This situation would result in delayed maintenance of the infrastructure. For the WSSs where the generated revenue is not enough to cater for competitive remuneration, means for sourcing additional funds are discussed in section 4.4.5.

5. *Root cause 5 of prolonged breakdown of infrastructure* - Water not supplied to people living close to the water supply infrastructure (RC13)

In 2 of the 10 case WSSs, infrastructure was vandalised for not supplying water to some of the people who lived along the pipelines. The people vandalised the infrastructure in order to punish those who had access to the water, and/or to access the water. This is corroborated by Admassu et al (2003) who state that DWS infrastructure is sometimes vandalised for the vandals to access the water. Vandalism increased the rate of breakdown of infrastructure. This affected the capacity to carry out maintenance of the infrastructure within a short time. This was the case because with so many breakdowns, it was not possible to attend to all the breakdowns at once. Consequently, there was delayed maintenance of some of the breakdowns.

Substantiating "water not supplied to people living close to the water supply infrastructure" as a root cause: If water was supplied to all the people who lived close to the water supply infrastructure, the infrastructure would not be vandalised. As such, the number of breakdowns would not be high. In that case, maintenance of the infrastructure would not delay. Therefore, water not supplied to people living close to the water supply infrastructure was one of the root causes of prolonged breakdown of infrastructure.

Efforts at the time of the study to prevent vandalism of water supply infrastructure

The DWS service providers for the case WSSs where the water supply infrastructure was vandalised sensitised the people who lived close to the water supply infrastructure on the importance of not vandalising the infrastructure. The people were also mobilised to assist to identify and arrest the vandals. These efforts, however, did not help to stop vandalism of the infrastructure.

The reason why water supply infrastructure was vandalised

Water supply infrastructure (e.g. pipelines) was vandalised because people who lived close to the infrastructure hence could easily identify and arrest the people who vandalised the infrastructure did not benefit from the infrastructure. Such people had no reason to spend their energies trying to protect the infrastructure that did not benefit them. Actually, those could be the people who vandalised the infrastructure to punish those who had access to the water, and/or to access the water.

Proposed tactic for preventing vandalism of water supply infrastructure

a - All people living close to water supply infrastructure should be supplied with water (T22)

All the people living close to water supply infrastructure should be supplied with water preferably produced and conveyed by the same infrastructure. This will ensure that the people appreciate the importance of the infrastructure. As such, the infrastructure will not be vandalised. If the water from the infrastructure cannot be supplied to some people living close to the water supply infrastructure, the reasons should be explained to the people. The people should then be allowed to request other amenities which should be provided by the DWS service provider. In one case WSS, the people living along a raw water pipeline but upstream of a water treatment plant were provided with water from hand-pump boreholes. This was the case because it was difficult to provide the villagers with water from the piped DWS system.

6. *Root cause 6 of prolonged breakdown of infrastructure* - Use of infrastructure beyond its useful life span without refurbishment (RC14)

In 7 of the 10 case WSSs, the infrastructure was used beyond its useful life span (an average of 25 years (Montgomery et al, 2009)) without being refurbished. Table 29 shows the years by which the infrastructure for the case WSSs should have been refurbished.

Table 29: The years by which the infrastructure should have been refurbished

Case WSS Number*	The year by which the infrastructure should have been refurbished
1	2010
2	2005
3	2010
4	2013
5	2000
6	1985
7	2005
8	2001
9	1997
10	1994

Note:

* These numbers are used to distinguish one case WSS from another and not to identify the systems.

Source: Design reports for upgrading works of the case WSSs

Except for case WSS numbers 2, 5 and 9 (which were refurbished 8, 13 and 11 years respectively later than the year when they should have been refurbished as shown in table 29), the rest of the case WSSs had not been refurbished by the time of this study (2014) although their useful life spans had expired earlier. Failure to refurbish the infrastructure by its design year resulted in the infrastructure breaking down frequently, and sometimes the breakdowns were major. One respondent stated that the infrastructure at the WSS where he worked broke down so often because it was very old, and had not been refurbished. The increased number of breakdowns and major breakdowns affected the capacity to maintain the infrastructure within a short time. As a result, there were prolonged breakdowns of the infrastructure.

Substantiating "use of infrastructure beyond its useful life span without refurbishment" as a root cause: If the infrastructure was refurbished by the time it reached its useful life time, it would not break down frequently nor result in major breakdowns. As such, there would be capacity to quickly maintain the parts that would break down once in a while and/or minor breakdowns. Therefore, use of infrastructure beyond its useful life span without refurbishment was one of the root causes of prolonged breakdown of infrastructure.

The reason why infrastructure could not be refurbished by the time of expiry of its useful life span

Infrastructure could not be refurbished by the time of expiry of its useful life span because the required materials and human resources were not available on time.

Proposed tactic for preventing frequent breakdown of infrastructure

a - Refurbish infrastructure before expiry of its useful life time (T23)

The need for DWS services will continue regardless of whether or not useful life time of infrastructure has expired. The exception to this is where alternative infrastructure has been developed or for some reason, there is no longer water demand. In the absence of the above exceptions, the infrastructure should be refurbished before expiry of its useful life time. This will ensure that the infrastructure does not break down frequently and/or the breakdowns are not major.

7. *Root cause 7 of prolonged breakdown of infrastructure* - Poor performance of designers (RC15)

It was noted in one of the case WSSs that the consultants did not prepare the best designs for pumps. The chosen type of pumps was not appropriate for silty water. The consultants selected this type of pumps because they did not know that the water becomes silty when strong winds blow. The consequence of this was that whenever strong winds blew the pumps were not operated to prevent them from breaking down. This finding is corroborated by RWSN (2010) which states that inappropriate technology leads to failure of water supply infrastructure. Stoppage of the pumps disrupted water supply because strong winds could blow for as long as 5 hours at one time.

Substantiating "poor performance of designers" as a root cause: If the consultants established the quality of the water throughout the year, appropriate technology should have been chosen. As such, the pumps would not be stopped. Therefore, poor performance of designers was one of the root causes of prolonged breakdown of the infrastructure.

The reason why performance of designers was poor

Performance of designers was poor because the consultants did not have enough knowledge of the local situation.

Proposed tactics for designers to select appropriate technology

a - Foreign consultants should partner with local consultants (T24)

To avoid the situation whereby inappropriate solutions are proposed by foreign consultants because they do not have adequate knowledge of the local situation, foreign consultants should be asked to partner with local consultants. Requests for proposals issued to consultants should require foreign consultants to partner with local consultants, and that foreign consultants who will not abide by this requirement should not be engaged. Follow-up should be made to ensure that it is the qualified local consultants (and not junior staff) who work with the foreign experts, and that the local consultants take part in the design.

b - Deliverables of designers should be critically evaluated (T25)

Project owners should ensure that deliverables from the designers are critically evaluated. The proposals should be cross-checked that they will indeed work in the local environment. Where the expertise to review the proposals from the designers is not available in the project owner's organisation, such expertise should be sourced from elsewhere. This was being practiced at the time of the research whereby designs were being submitted for review to a team of experts from various institutions working on NWDP in the DWS sector in Malawi.

8. *Root cause 8 of prolonged breakdown of infrastructure* - Project owner's refusal to change its predetermined requirements in spite of the consultants' advice (RC16)

It was noted in one of the case WSSs that despite the consultants advising that the pipes that should be laid across the rivers should be of steel type (or similar), the project owner insisted that PVC pipes should be used because they would also work. Because of the project owner's insistence, PVC pipes were installed. After some time, the river beds started getting eroded away, and this led to movements of the pipe supports. With the movements of the supports, the PVC pipes broke. Maintenance works (which involved purchase of appropriate pipes and construction of supports) took long and this resulted in prolonged breakdown of the infrastructure. This would not have happened if steel pipes (or similar) were used in the first place.

Substantiating "project owner's refusal to change its predetermined requirements in spite of the experts' advice" as a root cause: If the project owner took heed of the consultant's advice, the appropriate type of pipes (technology) would have been chosen. As such, the infrastructure would not break down and require a lot of time to maintain. Therefore, project owner's refusal to change its predetermined requirements in spite of the experts' advice was one of the root causes of prolonged breakdown of infrastructure.

The reason why project owners insisted on using their predetermined requirements

Some project owners insisted on using their predetermined requirements because they thought they knew better than the consultants.

Proposed tactic for project owners to allow designers to select appropriate technology

a - A clause shifting blame of the cause of infrastructure failure from consultants to project owner should be included in consultancy contracts (T26)

Project owners (DWS service providers) should take advice from consultants on what is the best solution. Since the project owners are the employer, the consultants are in a weaker position to argue with them. Therefore, the only way that the project owner will be forced to accept the changes proposed by the consultants is to put a clause in the contract that threatens the client (project owner). It is, therefore, proposed by some interviewees that in any contract between a project owner and a consultant, the following clause or similar should be included: *"If the client refuses to make changes to its predetermined requirements in spite of the consultant's advice, the consultant will terminate the contract and report the matter to the department responsible for public* *procurement. On the other hand, if the consultants do not do the foregoing, and a problem surfaces later because of the client's refusal to accept the changes, the consultants will take the blame and be banned from working in Malawi for at least 10 years"*. This clause will ensure that the clients and consultants come up with requirements that are for the good of water supply systems and not otherwise.

9. *Root cause 9 of prolonged breakdown of infrastructure* - Project sponsors who do not have adequate knowledge of local situation but insist to prescribe requirements (RC17)

In one of the case WSSs, project sponsors provided requirements for the infrastructure to be constructed. The prescribed requirements resulted in selection of HDPE pipes. The HDPE pipes, which are light, were installed in the lake, where the waves get tough when strong winds blow. The pipes kept being washed around by the waves to the extent that the pipeline broke down making the entire infrastructure not to function. Maintenance of the pipeline in the lake took long because it involved hiring of equipment like a ship and experts such as divers. This resulted in prolonged breakdown of the infrastructure.

Substantiating "project sponsors who do not have adequate knowledge of local situation but insist to prescribe requirements" as a root cause: If the project sponsors had adequate knowledge of the local situation (i.e. strong waves form on the lake whenever there are strong winds), they would not insist on using their prescribed requirements. As such, appropriate type of pipes would have been used (Binder, 2008). In that case, the infrastructure would not break down and require use of a ship and divers which took long to hire. Therefore, project sponsors who do not have adequate knowledge of local situation but insist to prescribe requirements was one of the root causes of prolonged breakdown of infrastructure.

The reason why project sponsors insisted on prescribing requirements

Some project sponsors insisted on prescribing requirements because they thought they knew better than the project owners.

Proposed tactic for project sponsors to allow designers to select appropriate technology

a- DWS service providers must not accept requirements prescribed by project sponsors which are likely not to work (T27)

Where it is clear that what the project sponsor proposes will not work, the DWS service provider should provide facts why they think what is being proposed will not work. If the project sponsor insists, the DWS service provider should then use whatever means or whichever people to convince the project sponsor not to use the proposed specifications. Actually, Carter and Rwamwanja (2006) advise that donors must be flexible, and understand the realities on the ground.

10. *Root cause 10 of prolonged breakdown of infrastructure* - Poor performance by contractors (RC18)

In three of the 10 case WSSs, the contractors did not carry out the works as per the specifications. The contractors installed pipelines at shallow depths into the ground. Consequently, those pipelines easily got broken even by ploughing the ground during cultivation. This shows that the poor work by the contractors resulted in poor quality infrastructure (pipelines) which easily broke down. RWSN (2010) had similar finding in its study whereby it was noted that poor construction leads to failure of water supply infrastructure. Maintenance of the breakdowns took long because the spare parts ran out of stock since there were too many breakdowns. This resulted in prolonged breakdown of the infrastructure.

Substantiating "poor performance by contractors" as a root cause: If the contractors carried out the works as per the specifications, the infrastructure would have been of good quality. Such infrastructure would not break down so easily and require a lot of spare parts some of which were not in stock. Therefore, poor performance by contractors was one of the root causes of prolonged breakdown of infrastructure.

The reason why contractors did not follow specifications when constructing facilities

Some contractors did not follow specifications when constructing facilities so that they could reduce costs to be incurred in the works and make bigger profit. They were comfortable to do this because they knew that the constructed facilities would not be assessed thoroughly at the time of hand-over from the contractor to the project owner.

Proposed tactic for ensuring constructed facilities work as required at the design stage

a - DWS service providers should assess the constructed facilities thoroughly to ensure compliance with the specifications (T28)

DWS service providers should assess the constructed facilities thoroughly to satisfy themselves that the facilities have been constructed in compliance with the specifications, and that the facilities' performance is as per the requirements. This should be done before the facilities are handed over from the contractor to the project owner (DWS service provider). The DWS service provider should not accept the facilities if they have not been constructed in compliance with the specifications, or that the facilities' performance does not satisfy the requirements. This is important because, as confirmed by a study conducted in Indonesia by Hodgkin (1994), high quality infrastructure contributes to DWS service sustainability.

11. *Root cause 11 of prolonged breakdown of infrastructure* - Climate change impact - extreme floods (RC19)

One of the climate change impacts is extreme floods. In one of the case WSSs, extreme floods washed away water intake weir. The weir, which had been in existence for only 2 years (2001 to 2003), was washed away because climate change increased the intensity of the floods (IPCC, 2007). With the short period that the weir existed, one may be tempted to speculate that the weir was washed away because it was either poorly designed or poorly constructed. While these speculations might not be far-fetched, the respondents stated that the magnitude of the flood which washed away the weir was unprecedented for the river; thereby suggesting that the weir was washed away because the flood was extreme. This is supported by the fact that the number of floods in Malawi has been increasing over the years (Malawi National Statistical Office, 2006b). Following the washing away of the weir, the whole water supply infrastructure stopped to function because raw water could not be abstracted. Due to unavailability of funds for constructing the weir again, it took 10 years for a replacement weir to be constructed.

In addition, extreme floods washed away a number of pipe sections in the case WSSs. With this, water supply to some areas was interrupted until new pipes were installed, which took days, weeks and in some cases months. The washing away of the infrastructure is not surprising as Liu and Deng (2011) and UNICEF-WHO (2011) note that extreme floods resulting from climate change affect infrastructure.

Substantiating "climate change impact - extreme floods" as a root cause: If it was not for the extreme floods (one of the climate change impacts), the infrastructure would not have broken down and taken long to maintain. Therefore, climate change impact - extreme floods was one of the root causes of prolonged breakdown of infrastructure.

The reason why extreme floods could not be reversed

Extreme floods could not be reversed because climate change impacts were irreversible in the short-term as noted by Chen et al (2010).

Proposed tactics for adapting to extreme floods resulting from climate change impacts

a - Monitor the trend of the magnitude of the floods that occur (T29)

DWS service providers should establish the trend of the magnitude of the floods that occur in the rivers across which water supply infrastructure (e.g. water intake weir, pipelines) was constructed.

b - Reconstruct infrastructure which is located across the rivers (T30)

If the projected trend of the magnitude of the floods shows that extreme floods capable of washing away the infrastructure will occur by a particular date, the infrastructure should be reconstructed or upgraded before that date so that the infrastructure is strong enough to resist the forces from the extreme floods. This tactic is supported by UNICEF-WHO (2011) who state that one way of adapting to extreme floods resulting from climate change is to maximise resilience of existing infrastructure. Otherwise, the infrastructure will be washed away and disrupt water supply.

4.3.6 Capacity to operate the infrastructure (CE6)

4.3.6.1 Factors that affected capacity to operate the infrastructure

Capacity to operate the infrastructure in the case WSSs was affected by the factors contained in the quotations in box 22.

Box 22: Factors that affected capacity to operate the infrastructure

> "The only issue that affects quantity of water supplied in this area is intermittent power supply" (Respondent No. 12-2)
>
> "Power is our biggest challenge. On average, in a month, we do not have power supply for 250 hours" (Respondent No. 1-1)
>
> "We are not able to provide continuous water supply because power supply is erratic … Power supply is available for only 8 hours per day on average" (Respondent No. 12-6)
>
> "I remember one incident whereby we had run out of chemicals and we had to close the

water treatment plant until we received the chemicals" (Respondent No. 11-12)

"Some plant operators do not carry out some water quality tests when they are tired, especially at night... They work for 12 hours instead of the recommended 8 hours" (Respondent No. 11-12)

"Our staff do not have keen interest in performing their duties because their motivation is low" (Respondent No. 11-12)

"Some of our staff members do not operate the infrastructure in the required manner because they have not been trained on how to operate this infrastructure" (Respondent No. 3-11)

The quotations in box 22 show that the infrastructure in some of the case WSSs was sometimes not operated in the required manner because:

i. Power supply was either unavailable or not adequate;
ii. Water purification chemicals were sometimes not available;
iii. The number of personnel deployed to operate the infrastructure did not match the amount of work to be done;
iv. The staff members were not motivated; and
v. The staff members did not receive appropriate training.

This implies that the capacity to operate the infrastructure in the case WSSs was affected by adequacy/availability of supplies (e.g. power supply, water purification chemicals), human resource management, and involvement of untrained and unmotivated personnel. These factors need to be managed for the capacity to operate the infrastructure to be sustained.

4.3.6.2 Consequence of not managing the factors

The factors that affected the capacity to operate the infrastructure in the required manner were not managed as required in some of the case WSSs as discussed in section 4.3.6.4. The consequence of not managing the factors in the required manner was that there was insufficient capacity to operate the infrastructure (Cq 6). This was the situation in 5 of the 10 case WSSs.

4.3.6.3 Strategy for managing capacity to operate the infrastructure

Ensuring that there is always sufficient capacity to operate DWS infrastructure in the required manner (**S6**)

This strategy is supported by Lockwood (2003) who advises that the requirements necessary to operate the infrastructure should be available in the required quantities and quality. To ensure that there is sufficient capacity to operate the infrastructure in the required manner, the root causes of insufficient capacity to operate the infrastructure should be addressed. The paragraphs that follow discuss the root causes and the proposed tactics for addressing them:

4.3.6.4 Root causes and how to manage them

This study has found out that there were 6 root causes of insufficient capacity to operate the infrastructure in the case WSSs. The 6 root causes as well as the other 5 factors that affected the capacity to operate the infrastructure are shown in figure 12, which is an extract from figure 6.

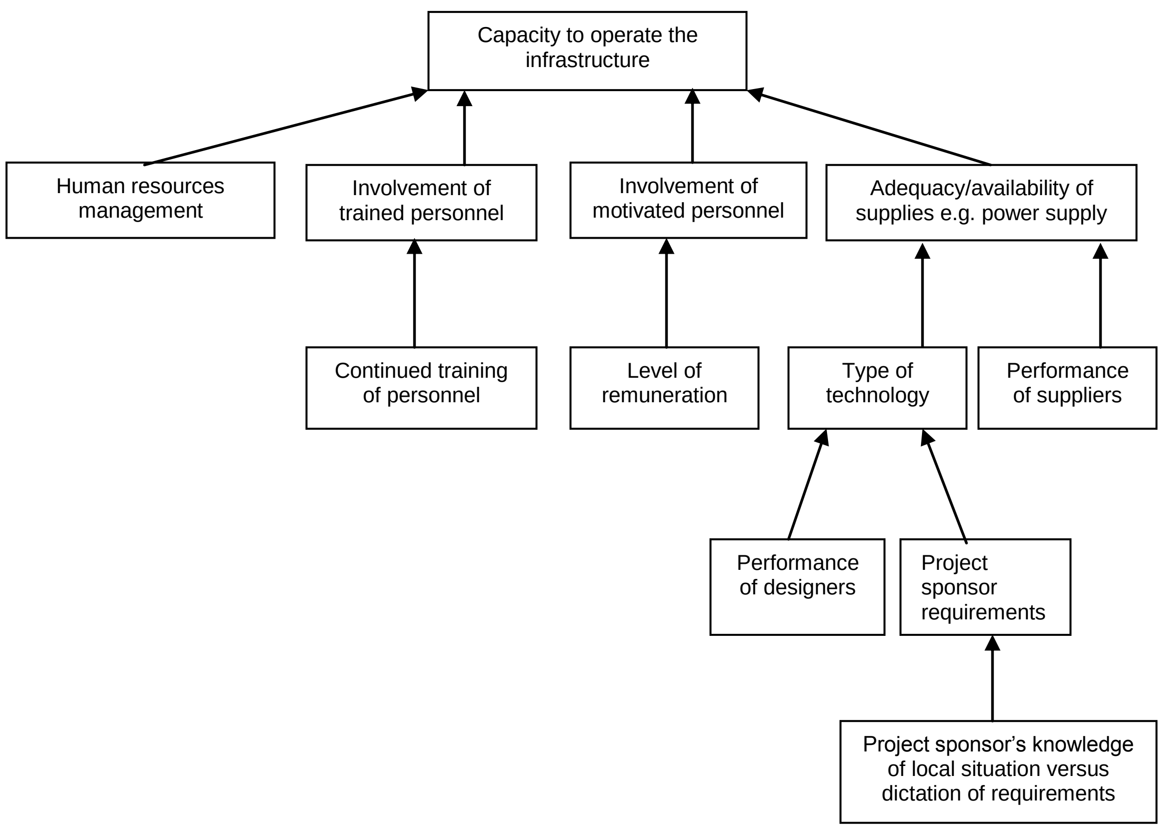


Figure 12: Relationship of the factors that affect operation of the infrastructure

The 6 root causes of insufficient capacity to operate the infrastructure, the reasons why they could not be addressed, and the proposed tactics for managing them are as follows:

1. *Root cause 1 for insufficient capacity to operate the infrastructure* - Number of personnel that does not consider the amount of work to be carried out (RC5)

The numbers of personnel that operated the infrastructure compared to the total numbers of personnel in the case WSSs are shown in table 30.

Table 30: Personnel that operated infrastructure in the case WSSs

Case WSS Number*	Personnel that operated infrastructure	Other personnel	Total number of personnel
1	6	10	16
2	4	8	12
3	21	115	136
4	3	7	10
5	7	11	18
6	6	2	8
7	3	3	6
8	58	405	463
Total	108	561	669

Note:

* These numbers are used to distinguish one case WSS from another and not to identify the systems. The numbers of personnel shown are for 8 case WSSs because the workers in 1 case WSS were volunteers whose number was not fixed, and there were no workers at one case WSS because the system was no longer operational.

Source: Records kept by the Scheme Managers

Table 30 shows that the operators of the infrastructure in the case WSSs constituted 16% of the total numbers of the personnel. Although the numbers of the plant operators look big, the nature of the plant in 6 of the 8 case WSSs shown in table 30 required that the operators should manage the plant for 24 hours per day. With this requirement, the plant operators were not enough in the 6 case WSSs. Consequently, the operators worked for 12 hours per day in the 6 case WSSs as opposed to the recommended maximum of 8 hours per day (Government of Malawi, 2000; ILO, 1935). One consequence of this was that when they got tired because of working for a long time, the plant operators stopped carrying out some activities like conducting regular (say, every 2 hours) water quality tests especially at night. Instead, they completed the forms with guessed figures. Failure to conduct the tests meant that certain adjustments which were supposed to be made to the operation of the plant were not made. This implies that the plant was not operated in the stipulated manner which could have affected the DWS services in one way or another.

Substantiating "Number of personnel that does not consider amount of work to be carried out" as a root cause: If the number of personnel allocated to operate the infrastructure was adequate, the staff should have been working for the recommended 8 hours per day. As such, they would have energy to operate the infrastructure in the stipulated manner. Therefore, number of personnel that does not consider the amount of work to be carried out was one of the root causes of insufficient capacity to operate the infrastructure.

The reason why the number of personnel could not match the amount of work carried out

The number of personnel could not match the amount of work carried out because either the total number of staff was not adequate or the staff members were not allocated equitably amongst the sections of the DWS institutions.

Proposed tactic for matching the number of personnel with the amount of work to be carried out

a - The number of staff should be based on the amount of work to be carried out (T7) - *details are on page 108*

2. *Root cause 2 for insufficient capacity to operate the infrastructure* - Limited continued training of staff (RC11)

As indicated in section 4.3.5, there was limited continued training of staff in all the 10 case WSSs. It was observed at one of the case WSSs that the pumps for dosing chlorine (disinfectant) to the water had broken down hence chlorine was dosed manually. Since the operators did not know the importance of dosing chlorine continuously (probably because they did not undergo follow-up training whereby the staff would be reminded of the importance of chlorine), they applied the chemical at once. The consequence of this was that there was too much chlorine in the water at one time, and no chlorine at all the rest of the time, as testified by the water users during the focus group discussions. This shows that the personnel who do not have the requisite knowledge do not operate the infrastructure in the stipulated manner.

Substantiating "limited continued training of staff" as a root cause: If there was continued training of staff, the personnel would know (and/or remember) the importance of dosing chlorine continuously. As such, the infrastructure would have been operated in the stipulated manner (Sara and Katz, 1998) e.g. chlorine would have been dosed continuously. Therefore, limited continued training of staff was one of the root causes of insufficient capacity to operate the infrastructure.

The reason why the challenge of limited continued training of staff could not be resolved

The challenge of limited continued training of staff could not be resolved because:

i. Only a few staff members were a priority to undergo training
ii. There was no appropriate training institution in the country for operative staff

Proposed tactics for ensuring continued training of staff

a - Prepare a training schedule for all staff members (T18) - *details are on page 144*

b - Implement training schedule (T19) - *details are on page 144*

c - Lobby training institutions in the country to introduce courses for staff working in water utilities (T20) - *details are on page 145*

3. *Root cause 3 for insufficient capacity to operate the infrastructure* - Low remuneration (RC12)

As indicated in section 4.3.5, salaries given to staff members in one of the 10 case WSSs were very low. In the other two case WSSs, the infrastructure was actually operated by unpaid volunteers. The consequence of this was that the personnel were not available to operate the infrastructure all the time they were required to do so. This resulted in the infrastructure not operated in the stipulated manner. For example, in one case WSS, the volunteers were not available for some days to remove the leaves that had clogged the opening of the water intake pipeline. Consequently, only a small amount of water flowed into the pipeline. The personnel were not available because they took time off to work on activities that would earn them a living.

Substantiating "low remuneration" as a root cause: If the remuneration was not low and/or all the people who operated the infrastructure received salaries (i.e. there were no unpaid volunteers), the personnel would have been motivated hence they would be available all the time to operate the infrastructure in the stipulated manner. Therefore, low remuneration was one of the root causes of insufficient capacity to operate the infrastructure.

The reason why the remuneration could not be increased

The remuneration could not be increased because the generated revenue was not much, in the affected case WSS.

Proposed tactic for motivating personnel

a - Remuneration should not be substantially less than that offered by other water supply utilities in the country (T21) - *details are on page 146*

4. *Root cause 4 for insufficient capacity to operate the infrastructure* - Poor performance of designers (RC15)

It was noted in all the 10 case WSSs that the consultants did not prepare the best designs in one way or another. As a result, the chosen technologies were not appropriate for the prevailing situations. A typical example was choosing of technologies that required a lot of power supply while on the ground power supply was either not adequate or sometimes not available at all. This was the case in all the 7 case WSSs where water was supplied by pumping. This was poor performance by the designers because one characteristic of appropriate technology is that it should work well with the available power supply (Binder, 2008).

Substantiating "poor performance of designers" as a root cause: If the consultants did a proper job, they would have known that electricity in all the case WSSs was not reliable. Therefore, appropriate technology should have been chosen. With appropriate technology, the capacity to operate the infrastructure should have been sufficient. Therefore, poor performance of designers was one of the root causes of insufficient capacity to operate the infrastructure.

The reason why performance of designers was poor

Performance of designers was poor because the consultants did not have enough knowledge of the local situation.

Proposed tactics for designers to select appropriate technology

a - Foreign consultants should partner with local consultants (T24) - *details are on page 150*

b - Deliverables of designers should be critically evaluated (T25) - *details are on page 150*

5. *Root cause 5 for insufficient capacity to operate the infrastructure* - Project sponsors who do not have adequate knowledge of local situation but insist to prescribe requirements (RC17)

In one of the case WSSs, project sponsors imposed specifications of a new water treatment plant to replace the old one. Use of the imposed specifications led to choice of a technology which was not appropriate for the situation. The new water treatment plant used much more power than the WSS could afford to pay. Consequently, sometimes certain components of the treatment plant were bypassed to reduce power usage.

Substantiating "project sponsors who do not have adequate knowledge of local situation but insist to prescribe requirements" as a root cause: If the project sponsors had adequate knowledge of the local situation (i.e. the amount of revenue generated by the water supply system), they would not have insisted on using their prescribed requirements. As such, appropriate technology that would take into account the capacity to operate it would have been chosen. In that case, there would be sufficient capacity to operate the infrastructure. After all, appropriate technologies are those which are easy to use, among other requirements (Haysom, 2006). Therefore, project sponsors who do not have adequate knowledge of local situation but insist to prescribe requirements was one of the root causes of insufficient capacity to operate the infrastructure.

The reason why project sponsors insisted on prescribing requirements

Some project sponsors insisted on prescribing requirements because they thought they knew better than the project owners.

Proposed tactic for project sponsors to allow designers to select appropriate technology

a- DWS service providers must not accept requirements prescribed by project sponsors which are likely not to work (T27) - *details are on page 152*

6. *Root cause 6 for insufficient capacity to operate the infrastructure* - Poor performance by suppliers (RC20)

In all the 7 case WSSs (out of 10) where power was required for water supply, the supplier of electricity did not provide the required measure of power supply, and sometimes the power supply was not available at all. As a consequence, the capacity to operate the infrastructure was insufficient or sometimes not available at all. WSP had similar findings in a study conducted in 1999 in South Asia (WSP, 2000).

Substantiating "poor performance by suppliers" as a root cause: If electricity was provided in the required measure and/or provided at all, there would be sufficient capacity to operate the infrastructure (RWSN, 2010). Therefore, poor performance by the supplier was one of the root causes of insufficient capacity to operate the infrastructure.

The reason why performance of suppliers was poor

Performance of suppliers was poor because the suppliers did not have capacity to provide the required supplies e.g. power supply

Proposed tactics for ensuring availability of supplies

a - Use different supplier (T31)

Where the performance of a particular supplier is not satisfactory, the DWS service provider should stop using the supplier and start using other suppliers. One respondent wished that power supply was not a monopoly business in Malawi so that he could switch suppliers.

b - Use different supplies (T32)

In the circumstances where the supplier is in a monopoly business, the DWS service provider should use technologies that utilise different supplies, and which can easily be accessed. An example is where some respondents indicated that they were conducting pilot projects to check if solar power could be used to pump water. This followed failure by the supplier of electricity, which is in a monopoly business, to provide electricity in the required manner.

4.3.7 Realisation of service provider expectations (CE7)

The DWS service providers in the case WSSs cited the following as their expectations when they supply water:

a. Providing water to the users at affordable price and at the same time there should be adequate funds for managing the WSSs properly; and
b. Reducing prevalence of waterborne diseases.

4.3.7.1 Factors that affected realisation of service provider expectations

Realisation of service provider expectations in the case WSSs was affected by the factors mentioned in the quotations in box 23.

Box 23: Factors that affected realisation of service provider expectations

> “...we are caught up in a situation where if we had money, do we invest in an area where it is very clear that the invested money will not be recovered ... From a business point of view, the priority level of this water supply system is very low ... the main challenge for this water supply system is small customer base” (Respondent No. 9-5)
>
> “Some consumers use ... less water than projected” (Respondent No. 8-11)
>
> “Use of water as assumed during design is not achieved because of tough economic situation. For those who pay for water on their own, the quantity of water used per capita is less than assumed while those whose water is paid for by institutions use much more than assumed ...” (Respondent No. 12-8)
>
> “We do not know how they come up with water bills. Meter readers do not come to our places to take meter readings. ...The only time that people from the service provider come to our places is to disconnect water supply” (Respondent No. 23a)
>
> “We need to know how water consumption is calculated” (Respondent No. 23c)
>
> “There is need to inform people of the times that water supply will be available in their areas during rationing of water” (Respondent No. 23d)
>
> “Our earnings here as a rural set-up are not as much. There is need that water tariffs should take this into account” (Respondent No. 26a)
>
> “In order to avoid high bills, water from the lake and boreholes is used for some activities like washing of clothes and utensils” (Respondent No. 26b)

The quotations in box 23 show that service provider expectations were not realised in some of the case WSSs because:

i. Senior managers’ expectation that a WSS should post profit when the customer base was very small was unrealistic;
ii. The quantities of water that were used sometimes were less than the projected quantities because of tough economic situation. The quantities used were less than what would lead to realisation of service provider expectations;
iii. Water users were not involved in making decisions on nor communicated to regarding water tariffs, calculation of quantity of water used, and the times that water would be available during rationing;
iv. Water users were not satisfied with certain processes and decisions like billing and water tariffs respectively; and

v. Some people used water from other sources to control amounts of water bills.

This implies that realisation of service provider expectations in the case WSSs was affected by realism of objectives, economic status of water users, continuity of use of supplied water as expected at the design stage, user satisfaction with service, and user involvement. These factors need to be managed for realisation of service provider expectations to be sustained.

4.3.7.2 Consequence of not managing the factors

The factors that affected realisation of service provider expectations were not managed as required in some of the case WSSs as discussed in section 4.3.7.4. The consequence of not managing the factors in the required manner was that service provider expectations were not realised (Cq 7). This was the situation in one of the 10 case WSSs.

4.3.7.3 Strategy for managing realisation of service provider expectations

Ensuring that there is always conducive environment for all people to use adequate quantities of potable water in order to realise health benefits and that there is adequate funds for managing the WSSs in the required manner (**S7**)

This strategy is supported by Parry-Jones et al (2001) and WELL (1998) who advise that for DWS services to be sustainable, there should be continued flow of benefits to all the stakeholders. One critical stakeholder whose expectations should be realised is DWS service provider (Al-Tmeemy et al, 2011). For DWS service provider to achieve this, the root causes of failure to realise service provider expectations should be addressed. The paragraphs that follow discuss the root causes and the proposed tactics for addressing them:

4.3.7.4 Root causes and how to manage them

This study has found out that there were 6 root causes of failure to realise service provider expectations in the case WSSs. The 6 root causes as well as the other 9 factors that affected realisation of service provider expectations are shown in figure 13, which is an extract from figure 6.

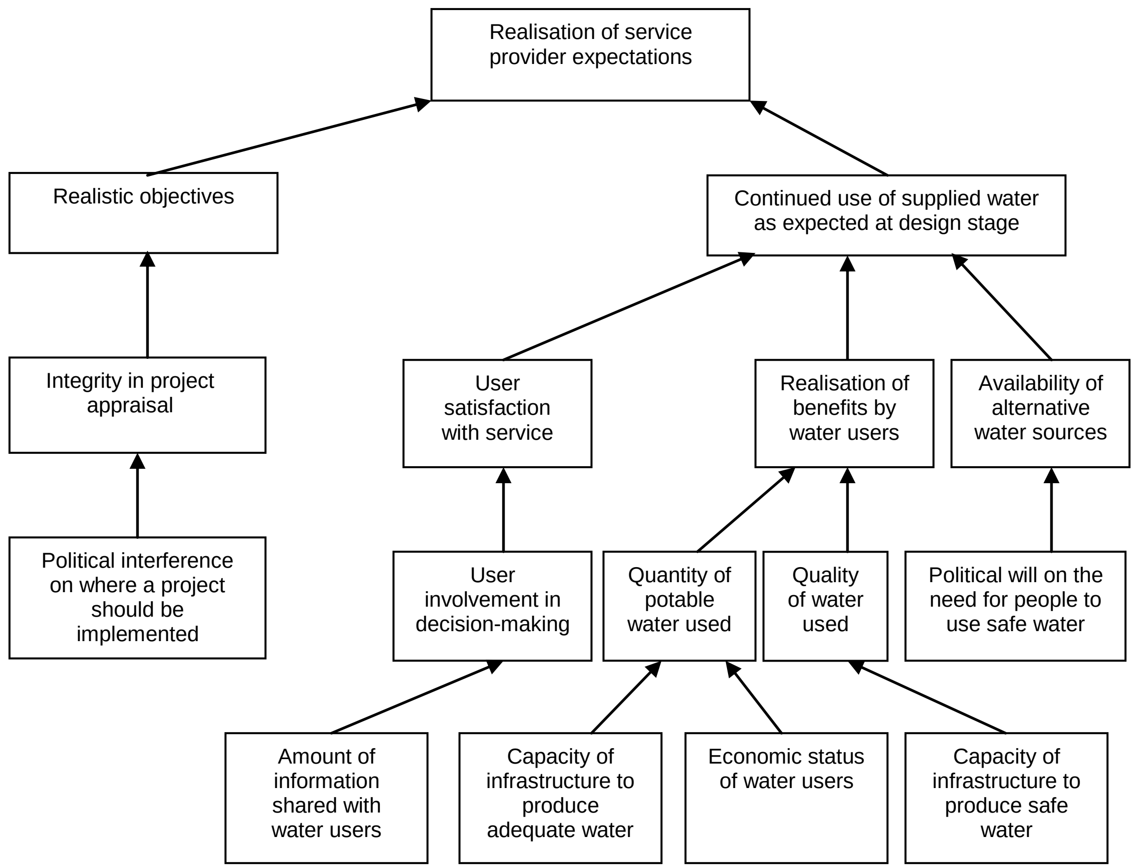


Figure 13: Relationship of factors that affect realisation of service provider expectations

The 6 root causes of failure to realise service provider expectations, the reasons why they could not be addressed, and the proposed tactics for managing them are as follows:

1. *Root cause 1 for failure to realise service provider expectations* - Political interference on where a project should be implemented (RC21)

It was noted that once politicians decide that a water supply system should be established at a certain place, they would stop at nothing until the water supply system was established. For example, one respondent stated that *"as an institution, we made a decision not to establish a water supply system at one particular centre because the project would not be financially viable. However, we were forced to go ahead with the project by the politicians regardless of its viability. Being a government entity, all that business thinking was thrown aside and we went ahead with the project" (*Respondent No. 11).

If the stumbling block to the politicians' wishes was the contents of project appraisal report, they would make sure that the appraisal report should be modified to suit their needs. Such reports, however, often contain contradicting information which misleads people. For example, it was noted in one of the case WSSs that the senior managers expected the WSS to cover its costs when it was quite clear on the ground that this could not be achieved because the customer base was too small (unrealistic objectives). The senior managers labelled the WSS a failure and refused to make any further investment in the WSS. Kutsch et al (2011) state that projects are sometimes said to have failed because the set objectives were unrealistic.

Substantiating "political interference on where a project should be implemented" as a root cause: If there was no political interference on where a project should be implemented, there would have been integrity in the appraisal of WSSs. The objectives would be realistic, hence achievable. Therefore, political interference on where a project should be implemented was one of the root causes of failure to realise service provider expectations.

The reason why staff members could not stick to professional conduct

Staff members could not stick to professional conduct in the appraisal of some of the DWS projects for fear of losing their jobs.

Proposed tactic for ensuring integrity in project appraisal

a - The ministry responsible for DWS and the DWS service providers should organise meetings to brief the politicians the consequences of implementing projects which do not satisfy appraisal criteria (T33)

The ministry responsible for DWS and the DWS service providers should organise meetings to brief the politicians the consequences of implementing projects which do not satisfy appraisal criteria. However, being an issue which is deep-rooted in the politicians, it is not expected that the politicians will stop interfering with the projects overnight, but they will eventually stop if sensitised.

2. *Root cause 2 for failure to realise service provider expectations* - Limited information shared with the water users (RC22)

It was noted that DWS service providers did not share much information with water users. Consequently, most water users did not have important information about DWS like how to calculate water consumption figures, timetables for water rationing, and new water tariffs, among others. Because of not being aware, for example, of why water tariffs might have been adjusted upwards, most water users felt the service providers were not justified to charge the new water tariffs. Noting that the water users did not support most of the decisions taken by the service providers (probably due to lack of information), for example, water tariff adjustments, the service providers decided not to involve the water users claiming that most of them were not objective in looking at the proposals from the DWS service providers. The consequence of not involving the water users in decision-making was that some decisions were not favourable to the water users. For instance, water tariffs charged were not affordable to some of the users. Consequently, the affected water users did not use as much water as assumed at the design stage. With this, the service provider expectations were not realised.

Substantiating "limited information shared with water users" as a root cause: If adequate information was shared with the water users, the water users should have been objective in contributing to the discussions on DWS matters, and they would even suggest some solutions. Involvement of the water users in decision-making would make the water users satisfied with the services offered by the service provider. In that case, there would be continued use of supplied water and the service provider expectations should have been realised. Therefore, limited information shared with the water users was one of the root causes of failure to realise service provider expectations.

The reason why adequate information could not be shared with water users

The DWS service providers did not share adequate information with water users because they felt that most water users were not objective in looking at the issues related to water supply.

Proposed tactic for ensuring involvement of water users in decision-making

a - DWS service providers should share with water users information that affects the water users (T34)

DWS service providers should provide as much information as possible on the challenges it is facing that will affect the water users in one way or another. The water users should also be briefed of the measures the DWS service provider intends to take to control the situation. Armed with the information, the water users will be able to make their contributions on how to deal with the challenges. Some water users may also network with people who can help.

However, it would be difficult for the service provider to interact with all the water users. There is, therefore, a need for the water users to elect a representative body with which the DWS service provider can deal. After all, the water users are already in need for such a body. The water users from one of the case WSSs expressed the need to have such a body, so that they can present their grievances to the DWS service provider through it.

3. *Root cause 3 for failure to realise service provider expectations* - Limited capacity of infrastructure to produce adequate water (R23); and
4. *Root cause 4 for failure to realise service provider expectations* - Limited capacity of infrastructure to produce safe water (R24)

As noted in section 4.1, some water users did not use safe nor adequate water partly because the infrastructure did not have capacity to supply safe and sufficient water. Use of unsafe and inadequate quantity of water made people to suffer from waterborne diseases (Calow et al, 2010; Howard and Bartram, 2003; Malawi Ministry of Health, 2011; WHO, 1993). This means that one of the major benefits of using potable water (prevention of diseases) was not realised.

Without achieving the expected benefits, the water users may not see the need to continue using potable water (Harvey and Reed, 2003; Roark et al, 1989). As such, quantities of water used by some consumers were less than expected. Failure to use the expected quantities of potable water by the users made the service provider not to realise its expectations.

Substantiating "limited capacity of infrastructure to produce adequate water; and limited capacity of infrastructure to produce safe water" as root causes: If the infrastructure had capacity to produce safe and adequate water, some water users would have used adequate quantities of potable water. In doing so, the water users would have realised the expected benefits of using potable water. As such, there would be continued use of supplied water in the projected quantities. This is supported by Carter et al (1999) who state that once users start realising benefits from potable water supply, demand for water supply by the users increases. Continued use of supplied water in the projected quantities would then have resulted in the service provider expectations being realised. Therefore, limited capacity of infrastructure to produce safe and adequate water was one of the root causes of failure to realise service provider expectations.

The reason why the infrastructure could not produce safe and adequate water

The infrastructure did not produce safe and adequate water because upgrading works were not carried out on time.

Proposed tactic for infrastructure to produce safe and adequate water

a - Upgrade existing water supply infrastructure in time (T16) - *details are on page 124*

5. *Root cause 5 for failure to realise service provider expectations* - Poor economic status of water users (RC25)

Because of the poor economic status of some water users (73.9% of the population in Malawi lived below the income poverty line of US$1.25 per day in 2010 (UNDP, 2013)), such users did not use as much water as expected for fear of high water bills. This is in line with the observation made by WSP (2009) that poor households find it difficult to pay monthly bills. Consequently, the amount of water used was not much to the extent that service provider expectations were not realised. This was the case because "*generated revenue is not adequate because the volume of water sold is not much*" (Respondent No. 12). This finding is supported by Howard and Bartram (2003) who state that socio-economic status affects the quantity of water used.

Apart from failing to generate enough revenue, other expectations such as prevention of diseases were not realised either, because the quantities of water used were not adequate. This is corroborated by Howard and Bartram (2003) who state that lack of access to adequate water supplies leads to the spread of diseases.

Substantiating "poor economic status of water users" as a root cause: If the economic status of water users was good, there would be continued use of the expected quantities of the supplied water, and the service provider expectations should have been realised. Therefore, poor economic status of water users was one of the root causes of failure to realise service provider expectations.

The reason why poor people could not use adequate quantities of potable water

Poor people did not use adequate quantities of potable water because they were too poor to afford bills of adequate quantities of potable water.

Proposed tactics for ensuring that the poor use adequate quantities of potable water

a - The ministry responsible for DWS and the DWS service providers should lobby the government to provide subsidies for the poor people to use adequate quantities of potable water (T35)

The ministry responsible for DWS and the DWS service providers should lobby the government to provide subsidies in order for the poor people to use adequate quantities of potable water. Otherwise, as indicated by almost all the water users who participated in the focus group discussions, the poor people used limited quantities of water to control water bills. Provision of subsidies by the government will be in line with the advice by Harvey and Reed (2003) and Morita-Lou and Waters (2008) that the poor should be served through subsidies. The details on the subsidies are provided in section 4.4.5.

b - DWS service providers should encourage water users to pay for water in small but frequent amounts (T36)

Some of the water users in Malawi who failed to pay for adequate quantities of potable water were able to pay for other services. Such other services included phones. The water users argued that they were able to pay for phone services because the required amounts were small while significant amounts were required to pay for water. The water users were not aware that they could pay small but frequent amounts towards their water bills. The DWS service providers should, therefore, encourage the water users to pay for water in small but frequent amounts. This would allow the water users to pay significant amounts towards water without noticing and hence grumbling.

6. *Root cause 6 for failure to realise service provider expectations* - Lack of political will on the need for people to use safe water (RC26)

It was noted that most politicians did not support enforcement of the stipulations in the Waterworks Act (Government of Malawi, 1995) that there should be no sources of unsafe water in the areas where there was piped potable water supply. Consequently, there were a number of unsafe water sources in the water areas. Since such sources had cheap water, some users collected large quantities of water from those sources and drew only a little from the piped potable water supply systems. The consequence of this was that the water supplied by the service providers was not used as much as expected at the design stage to the extent that service provider expectations were not realised.

Substantiating "lack of political will on the need for people to use safe water " as a root cause: If there was political will on the need for people to use safe water, sources of unsafe water would be closed. If the sources of unsafe water were closed, there would be continued use of the expected quantities of the supplied water by some users, and the service provider expectations should have been realised. Therefore, lack of political will on the need for people to use safe water was one of the root causes of failure to realise service provider expectations.

The reason why the politicians could not support closure of sources of unsafe water in potable water supply areas

Politicians could not support closure of sources of unsafe water in potable water supply areas because they thought keeping unsafe water sources would make them popular because water from those sources was cheap.

Proposed tactic for ensuring that sources of unsafe water are closed in potable water supply areas

a - The ministry responsible for DWS and the DWS service providers should organise meetings to brief the politicians the dangers of people using unsafe water (T37)

The ministry responsible for DWS and the DWS service providers should organise meetings to brief the politicians the dangers of people using unsafe water. With regular such meetings, the politicians will understand the concept and change their behaviour of providing and/or allowing existence of sources of unsafe water in the areas where there is potable water supply.

The discussions in this section (section 4.3) have shown that there are seven consequences of not managing the factors that affect sustainability of DWS services properly. The consequences are:

Cq1 - Inadequate quantity of available raw water;
Cq2 - Poor quality raw water;
Cq3 - Insufficient capacity of infrastructure to produce and supply adequate water;
Cq4 - Insufficient capacity of infrastructure to produce safe water;
Cq5 - Prolonged breakdown of infrastructure;
Cq6 - Insufficient capacity to operate the infrastructure; and
Cq7 - Failure to realise service provider expectations.

These consequences are a result of interaction of the factors whose causes are the root causes listed on pages 94 and 95, and discussed in the subsequent subsections.

To prevent occurrence of these consequences, seven strategies have been proposed in this section (section 4.3). The proposed strategies are:

S1 - Ensuring that raw water for DWS is always in sufficient quantity to satisfy the demand and is at a place from where it can be supplied in a cost-effective way;

S2 - Ensuring that raw water for DWS is always of a quality that can be treated by the existing infrastructure in a cost-effective way;

S3 - Ensuring that infrastructure for DWS always has sufficient capacity to produce and supply adequate water for the demand;

S4 - Ensuring that infrastructure for DWS always has sufficient capacity to produce water which is safe for human consumption;

S5 - Ensuring that broken down infrastructure is maintained within a short time;

S6 - Ensuring that there is always sufficient capacity to operate DWS infrastructure in the required manner; and

S7 - Ensuring that there is always conducive environment for all people to use adequate quantities of potable water in order to realise health benefits and that there is adequate funds for managing the WSSs in the required manner.

In this section (section 4.3), the following 37 tactics (which deal with structural, procedural and process issues) have also been proposed to safeguard sustainability of DWS services:

T1 - Declare water catchment area as a protected area;

T2 - Manage water catchment area;

T3 - Monitor water consumption figures for users;

T4 - Maintain leaking facilities;

T5 - Prepare a list of required spare parts and appropriate maintenance tools;

T6 - Prioritise and enforce purchase of spare parts and appropriate maintenance tools;

T7 - The number of staff should be based on the amount of work to be carried out

T8 - DWS service providers should be proactive in ensuring that their water rights are not violated;

T9 - Monitor the trend of the quantity of available raw water;

T10 - Develop and use alternative/additional water source;

T11 - Authorities responsible for land development should be advised not to allow additional people and developments in the affected area;

T12 - Relocate the affected settlement to a new area

T13 - Government should provide financing for DWS systems which are not cost-effective;

T14 - Construct water impoundment structures;

T15 - Monitor the trend of the quality of available raw water;

T16 - Upgrade existing water supply infrastructure in time;

T17 - Monitor the trend of the water demand growth;

T18 - Prepare a training schedule for all staff members;

T19 - Implement training schedule;

T20 - Lobby training institutions in the country to introduce courses for staff working in water utilities;

T21 - Remuneration should not be substantially less than that offered by other water supply utilities in the country;

T22 - All people living close to water supply infrastructure should be supplied with water;

T23 - Refurbish infrastructure before expiry of its useful life time;

T24 - Foreign consultants should partner with local consultants;

T25 - Deliverables of designers should be critically evaluated;

T26 - A clause shifting blame of the cause of infrastructure failure from consultants to project owner should be included in consultancy contracts;

T27 - DWS service providers must not accept requirements prescribed by project sponsors which are likely not to work;

T28 - DWS service providers should assess the constructed facilities thoroughly to ensure compliance with the specifications;

T29 - Monitor the trend of the magnitude of the floods that occur;

T30 - Reconstruct infrastructure which is located across the rivers;

T31 - Use different supplier;

T32 - Use different supplies;

T33 - The ministry responsible for DWS and the DWS service providers should organise meetings to brief the politicians the consequences of implementing projects which do not satisfy appraisal criteria;

T34 - DWS service providers should share with water users information that affects the water users;

T35 - The ministry responsible for DWS and the DWS service providers should lobby the government to provide subsidies for the poor people to use adequate quantities of potable water;

T36 - DWS service providers should encourage water users to pay for water in small but frequent amounts; and

T37 - The ministry responsible for DWS and the DWS service providers should organise meetings to brief the politicians the dangers of people using unsafe water.

While to some extent, some of the above seven strategies and 37 tactics had individually already been identified by some researchers as the strategies and tactics for addressing certain elements of the DWS sustainability (Abrams, 1998; Al-Tmeemy et al, 2011; Carter et al,1999; Lockwood, 2003), this research has enhanced and put them together into comprehensive lists of seven strategies and 37 tactics respectively for facilitating sustainability of DWS services in Malawi. The development of these comprehensive lists of the strategies and tactics will make it possible for all the factors that affect sustainability of DWS services in Malawi to be managed.

The other issue from this section (section 4.3) is that, based on the way the factors have been laid out in figure 6, the 7 combined effects serve as the names of the new categories of the sustainability factors for DWS services. This categorisation is different from the categorisation in the literature (section 2.5) in that all the factors that affect a particular issue are grouped under one category.

4.4 REQUIREMENTS FOR EFFECTIVE IMPLEMENTATION OF STRATEGIES

The strategies and tactics discussed in sections 4.3.1 to 4.3.7 cannot be implemented effectively if some requirements are not available. The requirements are different from the strategies and tactics because they are not what is directly required for sustainability of DWS services. This is the case because the requirements can be substituted while the strategies and tactics cannot. For example, if funds are required to develop a new water source, where funds is a requirement, and development of a new water source is a tactic, human resources and equipment can be provided in the place of funds, but a new water source has to be a new water source. However, whether directly or as substitutes, the requirements have to be available otherwise the strategies and tactics cannot be implemented effectively. For instance, if the available funds are not adequate, a new water source that may be developed might be of inadequate capacity. This happened to one of the case WSSs.

The research has established that the following are the critical requirements for effective implementation of the strategies and tactics.

4.4.1 External support (CR1)

External support is one of the critical requirements for effective implementation of strategies and tactics for sustainability of DWS services in the case WSSs. The quotations in box 24 from the interviewees substantiate this finding:

Box 24: Substantiating *'External support'* as a critical requirement

> "Although water boards are commercial entities, government should still come in to develop new water sources because such works are very expensive that water boards cannot afford on their own" (Respondent No. 2-11)
>
> "Multipurpose dams would be financially viable in that repayment would not only come from water consumers" (Respondent No. 9-11)

The quotations in box 24 show that the Water Boards could not implement huge-cost projects without external support; in this case financial support. The huge-cost projects are required to increase the capacity of the infrastructure which is a strategy for sustaining DWS services.

a. Why was there no external support?

The Water Boards in Malawi (which are Government owned companies) were classified as commercial entities (Government of Malawi, 1995). As such, they did not get any subvention from government. While this was the case, the revenue generated by the Water Boards was not adequate to implement huge-cost projects such as dams. This entails that there was a need for external support for the Water Boards to implement huge-cost projects like dams.

b. What should be done for there to be external support?

The ministry responsible for water supply was aware that the Water Boards did not have financial capacity to implement huge-cost projects like dams. As such, there was already a proposal that construction of dams should be done by, and the dams be owned by the Department of Water Resources in the ministry responsible for water supply.

While the respondents welcomed the proposal, it was indicated that this should not only cover dams but other huge-cost projects as well. The respondents added that there was a need for a policy which should clarify how the external support would be administered. The policy should, among others, include the criteria on which decisions would be based regarding which DWS service providers would be required to pay back part of the external support and how much. The other issues that need to be clarified in the policy are which entity should be responsible to manage the external support and what lead time should be allowed when applying for external support. The source of funds to be used for external support also needs to be clarified. One source of funds are development partners. This, of course, will require reversal of poor advocacy of DWS issues at national level as advised by UNDP-WSP in 2006. It should be noted that once DWS is recognised as an important sub-sector, there is high possibility that development partners will provide financing for DWS projects. On the other hand, when governments do not portray DWS as an important sub-sector, external support drops. For example, external support for DWS in Malawi dropped from US$ 14 million in 2003/04 to US$ 2 million in 2005/06 because DWS was not prominent in the Poverty Reduction Strategy Paper (UNDP-WSP, 2006).

Apart from provision of funds or construction of dams on behalf of DWS service providers, external support can also be in a form of stakeholders providing their input in the activities being carried out by the service provider, as well as services, works and goods provided to the service provider at no cost to the service provider.

4.4.2 Supervision of subordinates (CR2)

Supervision of subordinates is another critical requirement for effective implementation of strategies and tactics for sustainability of DWS services in the case WSSs. The quotations in box 25 from the interviewees substantiate this finding:

Box 25: Substantiating *'Supervision of subordinates'* as a critical requirement

> "It is good to have a Board of Directors that scrutinises performance of management in that you perfect your performance as you go other than to be told later that you did not do a good job" (Respondent No. 2-11)
>
> "We know that someone is watching us hence we should be vigilant on the quality of water that we produce. So far results of water quality tests from independent monitoring have been very good" (Respondent No. 3)
>
> "I would like to be visited by my superiors because then they can tell me where I am doing well and where I need to improve" (Respondent No. 14-7)

The quotations in box 25 show that supervision of subordinates affected the way subordinates performed their duties. The duties were performed well where there was close supervision. Good performance of duties, which may include implementation of strategies and tactics for sustainability of DWS services, would result in effective implementation of the strategies and tactics.

a. Why was there no close supervision of subordinates?

The situation at the time of the study was that most supervisors did not visit the work places of the subordinates. One respondent stated that *"our supervisors do not visit the water supply systems regularly. For example, for 3 years that I have been here, my supervisor has not visited us"* (Respondent No. 21-7)

It has also been noted that there was no feedback on the reports that subordinates submitted. One respondent stated that *"I doubt if our reports are reviewed by the officials in the government. We have never received any feedback on our reports"* (Respondent No. 11)

Some supervisors who were interviewed cited limited budgetary allocation as the reason why they did not supervise their subordinates closely. On the review of the reports, it was indicated that the challenge was that there was no unit in the ministry responsible for water supply assigned to review the reports submitted by the WSSs. It was also indicated that some of the supervisors were not competent to review the reports because they did not have the appropriate qualifications and experience.

b. What should be done for the subordinates to be supervised closely?

The recommendations on how to deal with limited financial resources are made under section 4.4.5. As regards review of reports, two solutions are proposed. One, at each stage of the reporting structure, the supervisor(s) should have qualifications and experience that will enable them to competently review the work of the subordinates. One respondent stated that he was impressed that the Board of Directors that they had at the time of the research was for the first time in the history of the institution able to review his work and guide how the work could be improved. He said this was the case because the directors had appropriate qualifications and experience for the job. The second solution is that at each stage of the reporting structure, there should be someone or a unit responsible for reviewing the work of the subordinates.

4.4.3 Safety of workers (CR3)

Safety of workers is one of the critical requirements for effective implementation of strategies and tactics for sustainability of DWS services in the case WSSs. The quotations in box 26 from the interviewees substantiate this finding:

Box 26: Substantiating *'Safety of workers'* as a critical requirement

> "There was an incident whereby one of our workers was mixing water purification chemicals without putting on protective clothing. High concentrated chemical splashed on him and he got burnt" (Respondent No. 11-12)
>
> "The process of producing water exposes staff to some hazardous conditions such as water purification chemicals as well as working with heavy equipment and materials which, if they can fall on them, can cause injuries. Staff are asked to wear protective clothing. We also have first aid kit to be used in case of injuries" (Respondent No. 3-11)
>
> "Staff members may contract diseases during handling of raw water like when collecting samples for quality tests" (Respondent No. 12)

The quotations in box 26 show that people working in the production and supply of drinking water are at a risk of contracting diseases or getting injured. This may affect implementation of strategies and tactics for sustainability of DWS services in that there could be fewer people working as others would be sick after contracting diseases or getting injured. In addition, when accidents occur, other people in the affected sections, would work with fear, and the strategies and tactics may not be implemented effectively. Luckily for the case WSSs, there was no evidence that somebody got sick or seriously injured in the process of producing and supplying water by the time of this study.

a. Why were workers not working in a safe environment?

Most of the DWS service providers in Malawi did not have health and safety policies. Instead, the occupational safety, health and welfare act (Government of Malawi, 1997b) was used. The problem is that acts of parliament, by their nature, provide general guidelines. As such, specific and detailed guidelines on how to deal with health and safety issues in the WSSs are not included in the act. In the absence of the details, the workers were not aware of the minimum safety standards. Consequently, as indicated in box 26, a worker could mix water purification chemicals without putting on protective clothing, among other dangerous acts.

b. What should be done for the workers to work in a safe environment?

Health and safety policy for WSSs should be developed. To avoid duplication of efforts, and also for easy enforcement, there should be one policy to guide all types of WSSs in the country.

4.4.4 Management arrangement of WSSs (CR4)

Clear management arrangement of a WSS is one of the critical requirements for effective implementation of strategies and tactics for sustainability of DWS services in the case WSSs. The quotations in box 27 from the interviewees substantiate this finding:

Box 27: Substantiating *'Clear management arrangement'* as a critical requirement

> "Although the water boards are supposed to operate as commercial entities, at the time they were established, they were told to take over all the water supply systems that were there without looking at commercial viability of the systems" (Respondent No. 9)
>
> "On paper, yes, activities are decentralised but resource-wise, no" (Respondent No. 16)

The quotations in box 27 show that management arrangements of WSSs in Malawi were not clear. The legislation showed that the Water Boards were commercial entities while in practice they were not; the legislation showed that the rural WSSs were under district councils, but in practice, funding for rehabilitation and upgrading works was provided to the ministry responsible for DWS. This affected implementation of strategies and tactics in that the assumptions made based on the provisions of the legislation did not hold e.g. the revenue generated by the Water Boards did not cover all the costs.

a. Why was management arrangement for WSSs not clear?

Management arrangements for the WSSs were not clear because the stipulations in the legislations were not followed in practice. A good example is the management arrangement for Water Boards. The Waterworks Act (1995) established Water Boards in Malawi as commercial entities. This was confirmed by the fact that the Water Boards did not receive government subventions. This was the case because it was expected that the Water Boards would sustain their operations using the revenue that they would generate. In practice, however, the Water Boards were not commercial. One respondent stated that out of the 23 WSSs under their institution, only 3 were financially viable. The Water Boards were asked to manage the town WSSs which were not financially viable because there was no other entity which had capacity to manage those WSSs.

The above arrangement was supported by one respondent. He argued that the Government did not intend to harm the Water Boards but let them supply water in the WSSs which were not financially viable through cross-subsidy. On this, another respondent counter-argued that *"if the money generated from some systems was not diverted to the systems which are not financially viable, the money should have been used for upgrading the water supply systems that generated the money"* (Respondent No. 9).

As regards rural WSSs, while these systems were decentralised to the district councils, financing for rehabilitation, upgrading and expansion works was still managed by the ministry responsible for DWS. Some respondents argued that funds for water supply could not be disbursed to the district councils because there was no capacity to manage the funds as well as the activities for which the funds were to be disbursed.

The above shows that at the time of this study, it was not clear whether Water Boards in Malawi were commercial or not; whether rural WSSs were decentralised to district councils or not.

b. What is the appropriate management arrangement for WSSs in Malawi?

A number of respondents were emphatic that the Water Boards should be allowed to operate as commercial entities. Some of the requirements for this to be achieved are that the WSSs under the Water Boards should be financially viable, and water tariffs charged should not only cover costs for operations, maintenance, upgrading works as well as servicing of loans but also reserves for extending water supply to other areas. The tariffs should, however, be reviewed and approved by a regulator. One respondent stated that *"there is need to have a regulator which would approve applications for water tariff increments based on provided justification"* (Respondent No. 6).

Adoption of the above proposal would mean that there will only be a few WSSs (about 10) to be managed by the Water Boards as most of the WSSs are not financially viable. Since the WSSs that will qualify to be managed by the Water Boards will be few, it is proposed that there should just be one Water Board across the country. This will be similar to power supply where there is only one institution.

If the above proposal will be implemented, there will be no entity to manage WSSs, which are not financially viable. For the reason that there is no capacity at the district level to manage DWS services (especially now that relatively big WSSs that are not financially viable will be dropped by the Water Boards), the WSSs cannot be managed by the district councils as it is the case in Uganda (an African country with the highest sustainability level of DWS services) where rural WSSs are managed by the district councils. Lack of capacity at the district level shows that decentralisation in Malawi has not matured. Lockwood and Smits (2011) state that in a mature decentralisation, lower tiers of government are not only given a mandate to deliver services but are also provided with adequate resources, capacities and decision-making power. Due to immaturity of decentralisation, it is proposed that the WSSs to be dropped by the Water Boards, and the rural WSSs be managed by a new entity. The new entity should be a parastatal organisation just like a water board but semi-commercial. Since the WSSs to be managed by this institution will not be financially viable, the financial gap should be filled by subsidy from the Government.

Since the proposed new institution will manage the rural WSSs as well, the ministry responsible for DWS will have no WSS to manage. This means that the ministry will only be responsible for providing policies, and monitoring implementation of the policies. This will be in line with what is advocated by Sara and Katz (1998) that governments should promote other than provide services. With this arrangement, the ministry will be able to assess the DWS services provided in the country objectively. Otherwise, it has been difficult for the ministry to point out shortfalls in the DWS services provided by others when there are similar shortfalls in the DWS services provided by the ministry.

It should be noted that it will not be the first time for the above proposed management arrangement to be used. It is in use in Ghana where it is said to be working well (IRC and Aguaconsult, 2011).

4.4.5 Use of adequate financial resources (CR5)

Use of adequate financial resources is one of the critical requirements for effective implementation of strategies and tactics for sustainability of DWS services in the case WSSs. The quotations in box 28 from the interviewees substantiate this finding:

Box 28: Substantiating *'Use of adequate financial resources'* as a critical requirement

"We wanted to have additional raw water source developed by 2015, but we have not even started because of the issue of financing" (Respondent No. 1-1)

"Although it was clear that groundwater was not enough, we were forced to go into a borehole project in 2002 because of limited funds available for the project" (Respondent No. 3-6)

"It has been difficult for the past two years to source funding for implementing the upgrading works for this water supply system" (Respondent No. 12)

"We are not able to extend the distribution pipelines to these people because we do not have funds to implement such projects" (Respondent No. 12)

"Proper maintenance is not carried out but improvisations because of cash-flow problems" (Respondent No. 8-11)

"Maintenance that is carried out is for the sake of keeping going. Proper maintenance is not carried out because of unavailability of adequate financing" (Respondent No. 11-11)

"For over two years, we have not been able to train and equip our divers because of cash-flow problems" (Respondent No. 2-4)

"Because of the social tariffs that we charge, we are not able to renew the water supply infrastructure..." (Respondent No. 11-11)

"Feasibility studies were conducted and preliminary designs prepared, but we have not yet sourced funds for detailed designs and construction works" (Respondent No. 3)

"Projects are implemented using external funding. Only one project was implemented with internally-generated revenue. Even with that, we had to borrow from a commercial bank and paid back later by instalments" (Respondent No. 11)

"When government approves a tariff which is lower than what we initially proposed, we drop implementation of expansion projects" (Respondent No. 2)

"Designs for rehabilitating the water supply system were already prepared. All what is remaining is identification of funds for the works" (Respondent No. 16)

The quotations in box 28 show that a whole range of activities were not carried out because of financial constraints. This is supported by the finding from the descriptive survey in which 65% of the respondents stated that funds available for water supply projects in Malawi were not adequate. The challenge of this, as stated by Binder (2008), is that it affects maintenance, technology to be used, and manpower to operate and maintain the system, among others. Some of the activities that were affected are the strategies and tactics for sustainability of DWS services.

a. Why were financial resources not adequate?

For the WSSs under the Water Boards, according to a number of respondents and the records, financial resources were not adequate because:

i. Water tariffs were low. At the time of this study, the average water tariff for the participating organisations was US$0.6 per m^3 while studies have shown that a cost-recovery tariff in Malawi is US$ 1 per m^3 (Banerjee et al, 2008; Foster and Shkaratan, 2011);
ii. A significant amount of water was not billed because it passed through faulty meters. The tendency was to assume that only a small amount of water passed through such meters to avoid being challenged by the customers. In one case WSS, out of a total of 18,000 meters, 2,000 were faulty.
iii. There were high rates of defaulting. For example, at the time of this study, the amount which the participating organisations had not collected although it was owed for more than the stipulated period of 30 days was as much as 2 times what they billed per month (Malawi Ministry of Water Development and Irrigation (2013a). One-half of the amount was owed for more than 3 months;
iv. Generated revenue was used to cross-subsidize WSSs under the same institution but which were not financially viable;
v. Generated revenue was used to cover costs for inefficiencies (e.g. too many staff members and high water losses); and
vi. A certain amount of revenue was not used in order to post a profit as expected by the Government.

Except for (ii) and (vi) which are not widely documented, if documented at all, all the above reasons are well-documented in the literature. The reasons are documented by researchers such as Foster and Shkaratan (2011) and Nedjoh et al (2003).

For the rural WSSs, again according to a number of respondents, financial resources were not adequate because:

i. Government did not allocate sufficient funds for DWS in the national budgets (actually allocations for DWS in the national budgets decreased consistently from 3.5% in 2008/2009 to 1.5% in 2012/2013 (Malawi Ministry of Water Development and Irrigation (2013b)); and
ii. Water users in some of the WSSs were not required to pay anything towards DWS.

The above reasons were also identified in the studies by Baumann and Danert (2008) and UNDP-WSP (2006).

b. What should be done for financial resources to be adequate?

To achieve sustainability of DWS services, there should be resources to perform the required activities (Carter and Rwamwanja, 2006). The financial resources for DWS can be made adequate by the following measures:

i. Water tariffs for the financially viable WSSs should be based on the full costs incurred;

Water tariffs for the financially viable WSSs should be based on the full costs incurred. However, to avoid overcharging the customers, the tariffs should be reviewed by a regulator before approval, and the costs resulting from inefficiencies of the service provider should not be included. For example, one respondent strongly felt that *"the staff members are too many. If this institution is to be managed commercially, the number of staff members has to be reduced by half"* (Respondent No. 7).

The situation in the case WSSs was that while there were inadequate numbers of staff maintaining the WSSs (table 24), there was a significant number of staff at the head offices for some of the DWS institutions. This is substantiated by the information in table 31.

Table 31: Number of personnel at the head offices for the participating organisations

Participating organisation Number*	Number of personnel working at		Total number of personnel	Personnel working at head office as a % of total personnel
	WSSs	Head Office		
1	378	85	463	18%
2	263	84	347	24%
3	338	59	397	15%
4	255	58	313	19%

Note:

* These numbers are used to distinguish one participating organisation from another and not to identify them. The provided information is for 4 participating organisations because some personnel at the head office for the fifth participating organisation worked in other subsectors as well and not only DWS.

Source: Records kept by Human Resources Departments

Table 31 shows that the percentage of staff who worked at the head offices of DWS institutions in Malawi ranged from 15% to 24%. The respondents from the institution where 15% of the staff worked at the head office stated that there was adequate number of staff at the head office to provide sufficient support to the WSSs. With 15% considered as being adequate, 24% is found to be on the higher side considering that activities carried out at head offices are mostly supportive in nature. This supports the claim by some of the respondents that staff members were too many in some of the DWS institutions. After all, there was similar geographical spread of the WSSs managed by the institution with 15% staff at the head office and those managed by the institution with 24% staff at the head office.

Removal of inefficiencies like overstaffing and high water losses from the costs to be included in the water tariffs is supported by WSP (2009). WSP (2009) advises that it may be possible to improve financial performance of WSSs without increasing the tariffs in real terms by simply improving efficiency of technical and commercial operations, and increasing connections.

ii. Government should allocate sufficient funds for DWS in the national budget

The Government has been arguing that tariffs for water should not be high because a good portion of the people are poor hence cannot afford high tariffs. However, in the words of one respondent *"what the government forgets is that there is always a cost for treating water, and rehabilitating and expanding the water supply systems. Where will the money to cover this cost come from?"* (Respondent No. 1). This is supported by a number of studies which established that raising and maintaining adequate funds is critical for service sustainability (Binder, 2008; Hodgkin, 1994; Morita-Lou and Waters, 2008). The other respondent reminds the Government that according to one of the 1992 Dublin principles, water is not only a social good but also an economic good. Hunter et al (2010) cite an example stating that where tariffs are set below the real running costs a vicious cycle gets established whereby the below-cost tariffs lead to inadequate investments in maintenance which results in deteriorating service and further unwillingness to pay even low tariffs.

With the above arguments, it is established that the citizenry which cannot afford to pay for water should be the reason why the Government should allocate enough funds in the budget. The funds should include the amount for subsidising the poor living in the areas where full-cost recovery tariffs will be charged. Morita-Lou and Waters (2008) explain that full cost recovery systems are beyond the means of the poor. Therefore, subsidies should be provided otherwise most of the vulnerable groups will collect water from unprotected sources. This will not be the first time that the Government of Malawi will provide subsidy. At the time of this study, the Government of Malawi was providing subsidy for farm inputs for the poor.

The rest of the money in the budget should be for topping up funds generated in the WSSs which are not financially viable. The funds should be for operations, maintenance, upgrading works, and extension of water supply to other areas. This is supported by Sara and Katz (1998) and the World Bank (1999) who state that financing would only be considered adequate if it covers O&M and generates savings for future repairs and system replacement.

Binder (2008) advises that government subsidies are the ones that are sustainable and not those from donors.

The other reason why the Government of Malawi should increase the allocation for DWS in the national budget is that it would be cheaper in the long-term to invest more in DWS and prevent water-borne diseases than to spend less on DWS and continue having significant number of cases of water-borne diseases. This is the case because investment in DWS would reduce the prevalence rate of water-borne diseases which would result in the reduction of the cost for healthcare related to water-borne diseases. On the other hand, if there is no significant investment in DWS, there will be no improvement in DWS and the prevalence rate of water-borne diseases may remain static as it is currently the case (see table 6). The Government of Malawi should, therefore, increase the allocation for DWS as opposed to the current scenario whereby funds spent on DWS are actually less than that spent on healthcare for water-borne diseases. For example, in 2013 MK4.6 billion was spent on DWS while up to MK4.8 billion was spent on healthcare for water-borne diseases based on the estimate by UNDP (2006) that treating of water-borne diseases in Sub-Saharan Africa costs governments at least 12% of the total health budgets each year (Malawi Ministry of Finance, 2013; UNDP, 2006).

The other challenges that result in the unavailability of adequate funds such as non-payment by some customers, and use of funds in non-priority areas will automatically be resolved once management arrangements are clarified (section 4.4.4), and appropriate legislation is in place.

4.4.6 Supportive legislation/policies (CR6)

Supportive legislation/policies is one of the critical requirements for effective implementation of strategies and tactics for sustainability of DWS services in the case WSSs. The quotation in box 29 from an interviewee substantiates this finding:

Box 29: Substantiating *'Supportive legislation/policies'* as a critical requirement

"Nobody asks for the report containing projections of the quantity and quality of water to be supplied in future because such a report is not prescribed in any of the legislation" (Respondent No. 29)

The quotation in box 29 shows that some people will not do anything unless it is in legislation/policies. This affects implementation of strategies and tactics for sustainability of DWS services in that certain activities which may not be carried out because they are not in the legislation are strategies/tactics for sustainability of DWS services. This shows how important it is to include whatever needs to be done or not to be done in the legislation/policies.

The discussions in this section (section 4.4) show the need to put in place legislation/policies on the following issues:

a. Regulator for DWS services;
b. Financing of huge-cost projects for the Water Boards;
c. Management of external support to the WSSs;
d. Health and safety of workers;
e. Management of financially viable WSSs; and
f. Management of WSSs which are not financially viable.

It is important to put the above legislation/policies in place because one factor that impacts on sustainability of DWS services is the existence of supportive policy and legal frameworks (Lockwood, 2003).

As mentioned at various places in this document, a regulator for DWS services is required in Malawi to, among others:

(i) Check and confirm that the water that is supplied is adequate and safe for human consumption;
(ii) Review and approve tariffs for water;
(iii) Ensure that institutions that provide DWS services carry out activities that will guarantee sustainability of DWS services;
(iv) Check and insist that the number of staff in the institutions that provide DWS services should be optimum;
(v) Check and insist that all staff members working in the institutions that provide DWS services should have appropriate qualifications and experience, and that they should

go for refresher courses at reasonable intervals so that they do not forget the basics in their areas of specialisation.

It will be noted from the discussions in this section (section 4.4) that 6 factors have been identified by the interviewees as the requirements which are critical for effective implementation of the strategies and tactics for sustainability of DWS services. The 6 critical requirements are:

CR1 - External support;
CR2 - Supervision of subordinates;
CR3 - Safety of workers;
CR4 - Clear management arrangement of WSSs;
CR5 - Adequate financial resources; and
CR6 - Supportive legislation/policies.

The above requirements had been identified by the researchers as some of the factors that affect sustainability of DWS services (Bhandari and Grant, 2007; Harvey, 2011; Hunter et al, 2010; Mimrose et al, 2011; Pinto and Slevin, 1989; UNCHS-Habitat, 1989). This study has, however, categorised them as the critical requirements for effective implementation of the strategies and tactics. This is the case because these factors do not cause sustainability failure of DWS services nor facilitate sustainability of DWS services. These factors can only ensure that the strategies and tactics are implemented effectively. The importance of categorising these factors in this manner, and having them as a set, is that where all these 6 critical requirements will be available at the required level as discussed in this section, the strategies and tactics for sustainability of DWS services will be implemented effectively.

These critical requirements should be assessed in advance, before implementation of the strategies and tactics, so that the measures for dealing with the shortfalls in them should already be identified at the planning stage.

Table 32 summarises the relationships amongst the combined effects of the factors, the consequences of not managing the factors in the required manner, the root causes of sustainability failure of DWS services, the strategies and tactics proposed to sustain DWS services, and the critical requirements for effective implementation of the proposed strategies and tactics.

Table 32: Summary of relationships of root causes, strategies and tactics

No.	**Combined effect of the factors** (section 4.2 - page 74)	**Consequence of not properly managing factors** (section 4.3 - pages 96 to 175)	**Strategies** (section 4.3 - pages 96 to 175)	**No.**	**Root cause factors** (section 4.3 - pages 96 to 175)	**Tactics** (section 4.3 - pages 96 to 175)	**Critical requirements for effective implementation of strategies and tactics** (section 4.4 - pages 175 to 189)
1	CE1 - Quantity of available raw water	Cq1 - Inadequate quantity of available raw water	S1 - Ensuring that raw water for DWS is always in sufficient quantity to satisfy the demand and is at a place from where it can be supplied in a cost-effective way	1	RC1	T1	
						T2	
				2	RC2	T3	
						T4	
				3& 4	RC3 & RC4	T5	
						T6	
				5	RC5	T7	CR1
				6	RC6	T8	
				7	RC7	T9	
						T10	
						T11	
						T12	
						T13	
				8	RC8	T9	
						T14	
						T10	
						T11	
2	CE2 - Quality of available raw water	Cq2 - Poor quality raw water	S2 - Ensuring that raw water for DWS is always of a quality that can be treated by the existing infrastructure in a cost-effective way	1	RC7	T15	
						T10	CR2
						T12	
						T13	
				2	RC1	T1	
						T2	
				3	RC8	T15	
						T16	
						T10	
3	CE3 - Capacity of infrastructure to produce and supply adequate water continually	Cq3 - Insufficient capacity of infrastructure to produce and supply adequate water	S3 - Ensuring that infrastructure for DWS always has sufficient capacity to produce and supply adequate water for the	1	RC9	T17	
						T16	
				2	RC10	T17	
						T16	

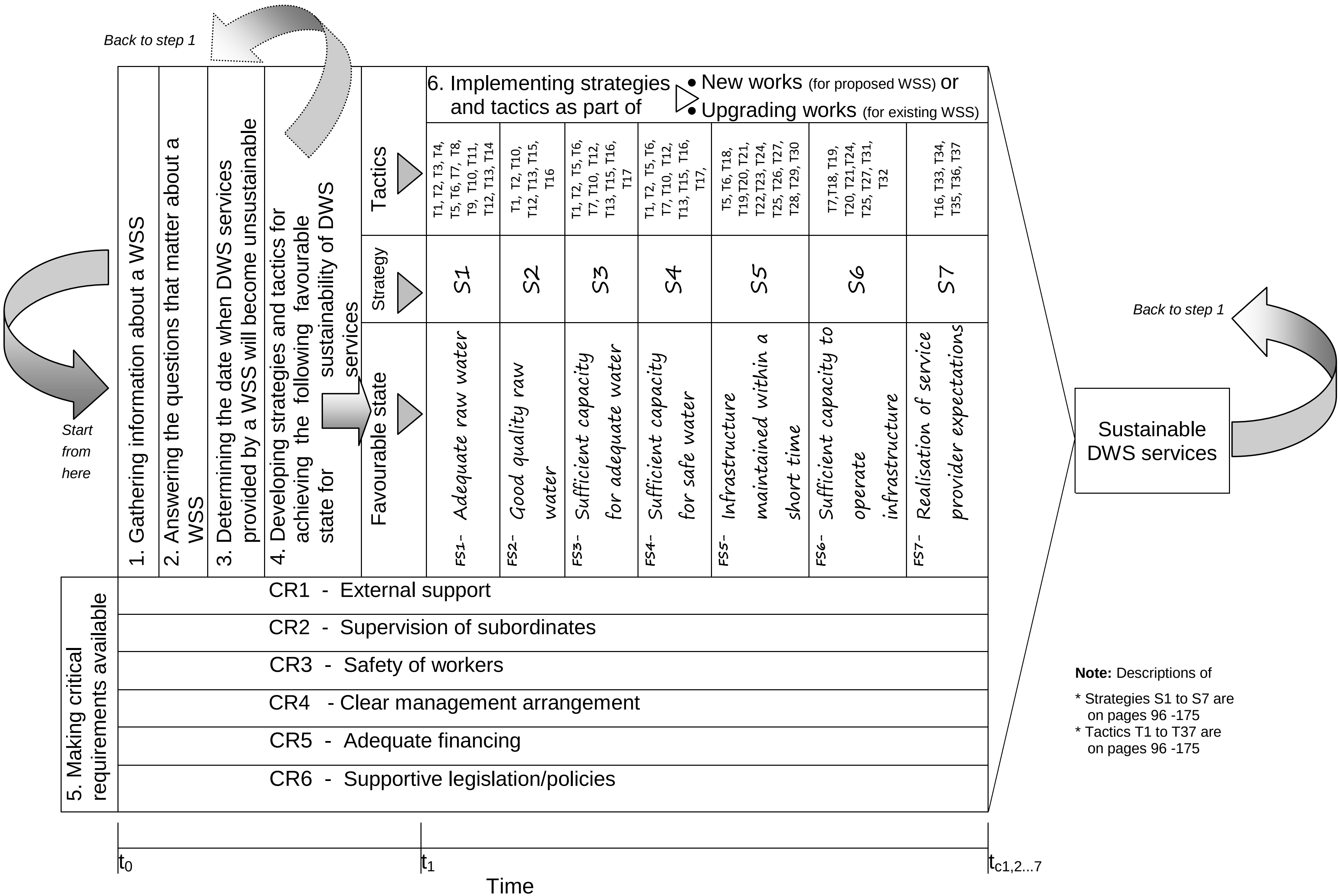
No.	**Combined effect of the factors** (section 4.2 - page 74)	**Consequence of not properly managing factors** (section 4.3 - pages 96 to 175)	**Strategies** (section 4.3 - pages 96 to 175)	**No.**	**Root cause factors** (section 4.3 - pages 96 to 175)	**Tactics** (section 4.3 - pages 96 to 175)	**Critical requirements for effective implementation of strategies and tactics** (section 4.4 - pages 175 to 189)
			demand	3	RC7	T15	CR3
						T16	
						T10	
						T12	
						T13	
				4	RC1	T1	
						T2	
				5& 6	RC3 & RC4	T5	
						T6	
				7	RC5	T7	
4	CE4 - Capacity of infrastructure to produce safe water continually	Cq4 - Insufficient capacity of infrastructure to produce safe water	S4 - Ensuring that infrastructure for DWS always has sufficient capacity to produce water which is safe for human consumption	1	RC9	T17	CR4
						T16	
				2	RC10	T17	
						T16	
				3	RC7	T15	
						T16	
						T10	
						T12	
						T13	
				4	RC1	T1	
						T2	
				5& 6	RC3 & RC4	T5	
						T6	
				7	RC5	T7	
5	CE5 - Continuity of infrastructure to function as required at the design stage	Cq5 - Prolonged breakdown of infrastructure	S5 - Ensuring that broken down infrastructure is maintained within a short time	1& 2	RC3 & RC4	T5	CR5
						T6	
				3	RC11	T18	
						T19	
						T20	
				4	RC12	T21	
				5	RC13	T22	

No.	**Combined effect of the factors** (section 4.2 - page 74)	**Consequence of not properly managing factors** (section 4.3 - pages 96 to 175)	**Strategies** (section 4.3 - pages 96 to 175)	**No.**	**Root cause factors** (section 4.3 - pages 96 to 175)	**Tactics** (section 4.3 - pages 96 to 175)	**Critical requirements for effective implementation of strategies and tactics** (section 4.4 - pages 175 to 189)
				6	RC14	T23	
				7	RC15	T24	
						T25	
				8	RC16	T26	
				9	RC17	T27	
				10	RC18	T28	
				11	RC19	T29	
						T30	
6	CE6 - Capacity to operate the infrastructure	Cq6 - Insufficient capacity to operate the infrastructure	S6 - Ensuring that there is always sufficient capacity to operate DWS infrastructure in the required manner	1	RC5	T7	CR6
				2	RC11	T18	
						T19	
						T20	
				3	RC12	T21	
				4	RC15	T24	
						T25	
				5	RC17	T27	
				6	RC20	T31	
						T32	
7	CE7 - Realisation of service provider expectations	Cq7 - Failure to realise service provider expectations	S7 - Ensuring that there is always conducive environment for all people to use adequate quantities of potable water in order to realise health benefits and that there is adequate funds for managing the WSSs in the required manner	1	RC21	T33	
				2	RC22	T34	
				3& 4	RC23 & RC24	T16	
				5	RC25	T35	
						T36	
				6	RC26	T37	

4.5 FRAMEWORK FOR SUSTAINABLE DWS SERVICES IN MALAWI

A framework for facilitating sustainability of DWS services in Malawi is discussed in this section. The framework will facilitate sustainability of DWS services by identifying the factors which are causing and/or are likely to cause sustainability failure of DWS services, and implementing strategies and tactics for preventing and/or reversing sustainability failure of the DWS services. The framework has been developed to fill the gap identified in section 2.6.3. It was noted in section 2.6.3 that the factors that are recommended to be managed for sustainability of DWS services (either individually or as sets of factors in the frameworks) do not address all the issues. Some frameworks address certain issues, and other frameworks address other issues. As a way of filling this gap (the recommended factors not addressing all the issues), the framework developed in this research is for holistic management of all the factors that affect or have potential to affect sustainability of DWS services in a WSS. Development of this type of a framework is supported by Niyi and Felix (2007), and Nkambule and Peter (2012) who state that all the possible factors should be considered in the management of sustainability of DWS services.

The framework has been developed based on what works in practice to sustain the quality and quantity of drinking water according to the findings of this research (sections 4.1 to 4.4). The framework is presented in figure 14.



Note: Descriptions of

* Strategies S1 to S7 are on pages 96 -175
* Tactics T1 to T37 are on pages 96 -175

Figure 14: The 6-step 7-strategy framework for sustainable DWS services in Malawi

Source: Author

The framework in figure 14 is known as ‘6-step 7-strategy framework for sustainable DWS services in Malawi’ to reflect the number of steps that need to be followed, and the maximum number of strategies that need to be employed to achieve sustainable DWS services. The 6 steps are as follows:

Step 1: Gathering information about a WSS

To identify the issues that affect or have potential to affect sustainability of DWS services in a WSS, there is a need to collect some information. The information to be collected should relate to the time a WSS was being designed, at present and in the future. This is supported by Sanders and Fitts (2011) who state that data for a WSS should be gathered at the time of design and throughout the life of a WSS. For this to be achieved, the practitioners in DWS in Malawi need to change their tendency of not collecting and storing correct data. Sugden (2003) notes that, at the time of his study, data related to drinking water supply in Malawi was limited, inaccurate and dissipated.

The information that is required, hence should be collected under this framework, is:

a. Quantity of available raw water;
b. Quality of available raw water;
c. Capacity of infrastructure to produce and supply adequate water;
d. Capacity of infrastructure to produce safe water;
e. Continuity of infrastructure to function as per design;
f. Capacity to operate the infrastructure; and
g. Realisation of service provider expectations

Once collected, the information should be analysed and trends established.

Step 2: Answering the questions that matter about a WSS; and
Step 3: Determining the date when DWS services will become unsustainable

Using the information collected in step 1, sustainability of DWS services in a WSS should be assessed. Assessment of the sustainability of DWS services in a WSS is important because the results from the assessment enlighten the authorities whether or not the DWS services are or will be sustainable. DWS services need to be sustainable because water supply is only useful if it is available all the time (Sanders and Fitts, 2011). The assessment of DWS sustainability also assists to identify sustainability-related challenges so that corrective measures can be taken on time (Khan, 2000).

The assessment of DWS sustainability should be conducted by answering the following questions:

a. Is raw water adequate for the demand? If yes, when will it become inadequate?
b. Is the quality of raw water good? If yes, when will it become poor?
c. Is the capacity of the infrastructure sufficient to produce and supply adequate water? If yes, when will the capacity of the infrastructure become insufficient to produce and supply adequate water?
d. Is the capacity of the infrastructure sufficient to produce safe water? If yes, when will the capacity of the infrastructure become insufficient to produce safe water?
e. Are the broken down parts of the infrastructure maintained within a short time? If yes, when will the broken down parts of the infrastructure not be maintained in a short time?
f. Is there adequate capacity to operate the infrastructure? If yes, when will the capacity not be adequate to operate the infrastructure?
g. Are the service provider expectations being realised? If yes, when will the service provider expectations not be realised?

The first parts of the above 7 questions will assist to find out whether the DWS services are sustainable or not. The answer ‘No’ to any of the first parts of the 7 questions means that the combined effect is in the unfavourable state for sustainability of DWS services (the opposite of FS1 to FS7). Therefore, the DWS services cannot be sustainable.

For each question where the answer is ‘No’, the root causes of the unfavourable state of the combined effects should be identified. The discussions in section 4.3 together with figure 6 may act as the starting point (as well as a checklist) for identifying the root causes of the unfavourable state of the combined effects.

The second parts of the 7 questions will assist to find out when the DWS services are likely to become unsustainable i.e. time $t_{c1,2...7}$, where t_{c1} is the date when the combined effect 1 will be in the unfavourable state for sustainability of DWS services, t_{c2} is the date when the combined effect 2 will be in the unfavourable state for sustainability of DWS services etc. The DWS services will become unsustainable at the time the state of any one combined effect will become unfavourable (see step 4).

Step 4: Developing strategies and tactics for achieving the favourable state

For the combined effects whose state is already unfavourable and/or those whose unfavourable state will occur in future as per the assessment in steps 2 and 3, appropriate strategies and tactics should be developed. The strategies and tactics should be for changing the unfavourable state of the combined effects to favourable state for sustainability of DWS services. Where the combined effects are in the favourable state, the strategies and tactics should be for preventing the favourable state from slipping into unfavourable state.

The favourable state for each of the combined effects as shown in figure 14 is:

FS1 - Adequate raw water (Abrams, 1998);

FS2 - Good quality raw water (Abrams, 1998);

FS3 - Sufficient capacity to produce and supply adequate water (Lockwood, 2003);

FS4 - Sufficient capacity to produce safe water (Lockwood, 2003);

FS5 - Maintenance of infrastructure within a short time when it breaks down (Carter et al,1999);

FS6 - Sufficient capacity to operate the infrastructure (Lockwood, 2003); and

FS7 - Realisation of service provider expectations (Al-Tmeemy et al, 2011).

Generic strategies and tactics outlined in section 4.3 may act as the starting point for developing strategies and tactics to be employed. Development of strategies and tactics is supported by Carter and Rwamwanja (2006) who advise that to achieve service sustainability, there should be plans on the required activities.

Depending on the length of the period between the time the strategies and tactics are developed, t_1 and when the DWS services are projected to become unsustainable ($t_{c1,2...7}$), implementation of the strategies and tactics can commence immediately, or can wait for some time. If implementation of the strategies and tactics will wait, then the process should start all over again beginning with gathering new information.

Step 5: Making critical requirements available

As discussed in section 4.4 and shown in the framework (figure 14), there are 6 critical requirements (CR1 to CR6) which may be required in all the 6 steps for sustainability of DWS services. The 6 critical requirements are external support, supervision of subordinates, safety of workers, clear management arrangement, adequate financing, and supportive legislation/policies. The availability of the 6 critical requirements will ensure that the strategies and tactics are implemented effectively. As such, mechanism should be put in place to ensure that all the 6 critical requirements are available. The discussions in section 4.4 may act as the starting point for identifying ways for ensuring availability of the 6 critical requirements.

Step 6: Implementing strategies and tactics

The strategies and tactics developed in step 4 should be implemented before time, $t_{c1,2...7}$ otherwise the DWS services will become unsustainable. The strategies and tactics should be implemented as part of new works where the concerned WSS is yet to be established or as part of upgrading works where the concerned WSS has been in existence for some time.

The cycle of the framework (step 1 to step 6 and back to step 1, or step 1 to step 4 and back to step 1) should be repeated continually including during implementation of strategies and tactics. This will assist to check if all the combined effects of the factors are in the favourable state for sustainability of DWS services (FS1 to FS7). If some combined effects are in the unfavourable state (the opposite of FS1 to FS7), or are likely to be in the unfavourable state in the future, the activities in the next cycle of the framework should identify the root causes, and appropriate strategies and tactics should be implemented accordingly.

One key advantage of using the framework developed in this research is that works for sustaining the DWS services can be planned well in advance. Such works can be staggered to fit the available financing contrary to the current practice where the required works are only determined after encountering challenges with sustainability of DWS services or when funds are sourced. For example, the biggest segment of the respondents in the descriptive survey (36%) stated that an analysis, for checking whether or not the quantity of raw water that will be available in future will be adequate for the demand, was only conducted after a problem was experienced. To solve the problem which was already being faced, all the required works were supposed to be implemented at once. However, implementation of all the required works at once, and after a long break, requires a lot of funds which may not be easy to source, as observed by the respondents.

4.6 THE RECOMMENDED WAY OF USING THE DEVELOPED FRAMEWORK

The ‘6-step 7-strategy framework for sustainable DWS services in Malawi’, presented in section 4.5, can be used by the practitioners, managers and policy makers to improve sustainability of DWS services. This section provides guidance on the best way of using the framework in practice.

For the information outlined in step 1 to be collected, there is a need for a staff member (or more, depending on the size of the WSS) to be assigned to gather the information. After being collected, the information should be submitted to the head office for the WSS. At the head office, there should be a unit to establish the trends of consumption figures for each water user, quantity and quality of raw water, water demand growth, and magnitude of floods, among others. The unit should analyse the established trends, and other information received from the WSSs.

After analysing the information, the unit should answer the questions that matter about a WSS, determine the date when the DWS services are likely to become unsustainable, and develop strategies and tactics i.e. steps 2, 3 and 4 in section 4.5. Mechanism for ensuring availability of the 6 critical requirements should be proposed.

The period between gathering information, and developing strategies and tactics as well as making arrangements for availability of the 6 critical requirements should not be longer than one year. For the sake of noting seasonal variation, and monitoring trends within a year, the period between collecting information and developing strategies and tactics should actually be 3 months.

The above details should be contained in a report which should be submitted to the senior managers of the institution that manages a WSS under review. After reviewing the report, the senior managers should submit the report to the DWS Services Regulator with a copy to the ministry responsible for DWS. At the Regulator's office, the unit responsible for sustainability of DWS services should review the report and satisfy itself that the report is correct. If not correct, the report should be sent back to be corrected. Once the report is correct, the unit responsible for sustainability of DWS services at the DWS Services Regulator should have keen interest and follow up with the institution that manages a particular WSS to ensure that the strategies and tactics outlined in their report are implemented on time.

The above discussions show that there should be staff at individual WSSs to gather information. Then there should be a unit at the head office which should compile a report for submission to senior management. In turn, the report should be submitted to the DWS Services Regulator which should have a unit responsible for sustainability of DWS services.

The advantage of using the above proposed reporting line is that authorities in the water supply sector will be aware that if certain strategies and tactics are not implemented by particular dates, DWS services will not be sustainable in certain WSSs. Therefore, the blame for sustainability failure of the DWS services cannot be put on the managers of the affected WSS only but also on the other authorities in the DWS sector.

The proposal of having a unit responsible for sustainability of DWS services at the DWS Service Regulator or the ministry responsible for DWS is supported by the respondents. One of the respondents stated that *“I wish there was a unit in Government that would monitor the quantity as well as quality of water that we supply to the users. Such a unit would assist us to justify why there is need to implement certain projects, much as the unit would expose our weaknesses”* (Respondent No. 1).

While waiting to establish the units recommended above, the existing units, say M&E and planning units at the Water Boards and the ministry responsible for DWS, should start compiling and reviewing the proposed reports. After all, these units are already carrying out some of the activities outlined in the framework developed in this research. All what is required is for the units to carry out all the outlined activities, and that the recommendations should be so specific that they can be implemented. For example, instead of stopping at saying that there is need to develop additional water source, the recommendation should go further to indicate the identified new source as well as the required resources to develop it.

Chapter summary

This chapter has presented the findings of this research. The presented findings are the results obtained from the data analyses that were conducted using various methods. The combined effects of the interactions of the factors that affect sustainability of DWS services have been identified from the analyses. For each identified combined effect, the root causes that make it to be in the unfavourable state for sustainability of DWS services have been identified. The strategies and tactics for addressing the root causes have been developed and have been presented in the chapter. Based on the identified combined effects, root causes, desired state of the combined effects, and developed strategies and tactics, a macro-level framework for sustainable DWS services in Malawi has been developed.

CHAPTER FIVE - CONCLUSIONS & RECOMMENDATIONS

Introduction

This chapter presents the conclusions which have been drawn from this research. The chapter presents a summary of the research findings, and offers recommendations on how sustainable DWS services can be provided in Malawi in view of the findings. The chapter also discusses how the objectives and the aim of the research have been accomplished. Thereafter, practical and theoretical contributions of this research to knowledge are discussed. Finally, the limitations of the research as well as further research that need to be conducted are discussed.

5.1 SUMMARY OF FINDINGS AND RECOMMENDATIONS

This research was conducted to find ways of facilitating sustainability of the recommended quality and quantity of drinking water in Malawi. This was after noting that the quality and quantity of drinking water in Malawi deteriorated as time passed after commissioning of the water supply systems. Root cause analysis, survey and multiple case studies were employed as research strategies for this study. Root cause analysis was conducted by five DWS experts, case studies involved ten water supply systems, and 40 respondents participated in the survey. All the participants and the case water supply systems were from Malawi. Both qualitative and quantitative data were collected and analysed in the study. Detailed findings of the research have been presented in chapter 4. A summary of the findings is as follows:

5.1.1 Sustainability of the quality and quantity of drinking water in Malawi

Some of the WSSs in Malawi supply water which is safe for human consumption while other WSSs provide unsafe water. As regards quantity of water supplied, all the WSSs in Malawi sometimes do not supply adequate water for the demand. This is the case despite that the supplied drinking water satisfies the demand and is safe for human consumption at the time of commissioning the water supply systems. This shows that supply of unsafe and/or inadequate drinking water in Malawi is due to the deterioration of the quality and quantity of drinking water as time passes after commissioning of the water supply systems.

On the part of the water users, the study has established that some of the water users draw less water from the piped WSSs than required, and the water that some of the water users use is not always safe for human consumption.

The water users draw less water from the piped WSSs because:

a. There is insufficient or no water flow to meet the users' needs; and
b. The water users do not have enough money to pay for adequate water.

(section 4.1.1)

To ensure that all water users have access to adequate quantities of potable water regardless of their economic status, it is recommended that the Government of Malawi should develop and implement a policy which should clearly stipulate how much should the water users in different income categories pay so that they afford the payments for the required quantities of potable water. If the costs for DWS will not be covered in full, the Government should provide subsidies to cover the shortfall.

The recommendation on how to address insufficient or no water flow at consumer taps is made under 5.1.2.

5.1.2 Reasons why supplied safe water does not satisfy the demand in Malawi

The flow of water at consumer taps is not sufficient to meet the users' needs in Malawi due to different combinations of the following reasons:

a. Quantity of available raw water is not adequate;
b. Quality of raw water is poor;
c. Capacity of infrastructure to produce and supply adequate water is not sufficient;
d. There are prolonged breakdowns of infrastructure;
e. Capacity to operate the infrastructure is not sufficient; and
f. Service provider expectations are not realised.

Therefore, to ensure sufficient flow of water at consumer taps, it is recommended that raw water should be of adequate quantity and of good quality, infrastructure should have sufficient capacity to produce and supply adequate water, infrastructure should be maintained within a short time when it breaks down, there should be sufficient capacity to operate the infrastructure, and service provider expectations should be realised. As such, it is recommended that the Government of Malawi should develop and implement a policy that will require that these parameters should be taken into account in the management of all piped water supply systems in Malawi. Specific tactics for achieving the above required status are discussed in section 4.3.

5.1.3 Reasons why water consumers in Malawi use unsafe water

About 60% of the people who are served by the WSSs that have been studied in this research sometimes use water which is not safe for human consumption and consequently suffer from waterborne diseases (i.e. implying that the DWS provided in these WSSs fails to achieve its main purpose of maintaining and/or improving public health for 60% of the people served). Unsafe water is used because:

a. Some of the WSSs no longer produce water which is safe for human consumption;
b. Quantities of water provided by some of the WSSs do not satisfy the demand of all the water users all the time. As such, some water users collect top-up water from unsafe sources and/or use water which has been stored for too long hence it is no longer safe; and
c. Some of the water users collect inadequate water from the WSSs because they are not able to pay for the required quantities of potable water.

(section 4.1.2)

Some of the WSSs no longer produce water which is safe for human consumption due to different combinations of the following reasons:

a. Quality of raw water is poor;
b. Capacity of infrastructure to produce safe water is not sufficient;
c. There are prolonged breakdowns of infrastructure; and
d. Capacity to operate the infrastructure is not sufficient.

Therefore, to ensure that the water that is produced is safe for human consumption, it is recommended that raw water should be of good quality, infrastructure should have sufficient capacity to produce safe water, infrastructure should be maintained within a short time when it breaks down, and there should be sufficient capacity to operate the infrastructure. It is, thus, recommended that the Government of Malawi should develop and implement a policy that will require that these parameters should be taken into account in the management of all piped water supply systems in Malawi. Specific tactics that can be employed to achieve the above required status are discussed in section 4.3. In addition, a legislation should be enacted that will require that drinking water supplied in the semi-urban and rural areas should also be safe for human consumption.

The recommendations made under sections 5.1.1 and 5.1.2 should be followed for the water users to access adequate quantities of potable water in spite of their economic status, and for there to be sufficient flow of water at consumer taps to meet the users' needs.

5.1.4 Repercussions of supply of inadequate and unsafe water in Malawi

Supply and/or drawing of less water from the WSSs than required, and use of unsafe water cause health, social and economic challenges to the water users in Malawi. In addition to the commonly documented challenges (section 1), supply and use of inadequate and/or unsafe water has the following challenges which are not widely documented, if documented at all:

a. People who have flush toilets only and no pit latrines at their homes are forced to use pit latrines at their neighbours' homes. This lowers the status of the people who use their neighbours' pit latrines;
b. People are forced to stay in nearby towns and commute to work a distance of about 20km to run away from water supply problems at their workplace towns. With this arrangement, transport costs are very high. Transport costs should have been lower if the people stayed within their workplace towns;
c. Some people pay a lot of money (probably more than they pay for potable water) for water that is drawn from unsafe sources such as hand-pump boreholes;
d. Some people spend up to two-thirds of the night (8pm to 4am) waiting for their turn to draw water. This time should have been used in a more productive way if potable water was readily available;
e. Fights erupt in the course of competing to be the first one to draw water. Some people get injured and others arrested because of this;
f. Some people travel as long as 7km searching for water to wash clothes. The money spent on transport should have been used for something else, and time taken to travel to where water is found should have been used in a more productive way if water was readily available;
g. Queuing for water for a long time away from guardians/spouses lead to increased cases of pre- and extra-material affairs as people have a lot of time idling. This results in early or unwanted pregnancies. Those affected either drop out of schools or their marriages break up. This may also lead to spread of HIV/AIDS; and

h. Marriage life is affected in that a spouse spends most of the night fetching water leaving the partner in bed at home. This results in mistrust between the spouses.

(section 4.1.1)

For people to use adequate and safe water, hence avoid encountering the above challenges as well as the commonly documented challenges of inadequate and unsafe water (section 1), the recommendations made under sections 5.1.1, 5.1.2 and 5.1.3 should be followed.

5.1.5 Factors that affect sustainability of DWS services in Malawi

There are 70 factors that affect sustainability of DWS services in Malawi, 63 of which had already been identified in the previous studies (not necessarily related to Malawi) while 7 have been identified in this study. The factors which have been identified in this study and may apply to other countries with similar contexts are:

AF1 - Integrity in project appraisal;
AF2 - Project owner's flexibility to change its predetermined requirements based on expert advice;
AF3 - Project sponsor's knowledge of local situation versus dictation of requirements;
AF4 - Quantity of potable water used;
AF5 - Quality of water used;
AF6 - Supply of water to the people living close to the water supply infrastructure; and
AF7 - Amount of information shared with the water users.

The discussions of how these additional factors affect sustainability of DWS services are included in section 4.3.

Of the 70 factors that affect sustainability of DWS services, 26 are the root causes that kick-start interaction of the factors which trigger the major causes of unsustainable DWS services (i.e. unfavourable state of the combined effects), while 7 are the combined effects of the interaction of the factors (symptoms). The rest of the factors are between the root causes and the combined effects (section 4.3). Based on this relationship, it is recommended that identification of the factors that affect sustainability of DWS services in particular WSSs should start with spotting of the combined effects which are in the unfavourable state or are likely to be in the unfavourable state, while sustaining of DWS services should be done by managing the root causes. This recommendation follows the fact that where the root causes are managed in the required manner (section 4.3), the combined effects of the factors do not fall into the unfavourable state that would cause sustainability failure of DWS services.

5.1.6 Management of root causes of sustainability failure of DWS in Malawi

In Malawi, not all the root causes of sustainability failure of DWS services are managed for each WSS. As such, interactions of the factors which end up triggering the major causes of unsustainable DWS services are kick-started. Consequently, each of the 10 case WSSs was affected by at least one major cause of unsustainable DWS services (unfavourable state of the combined effects) thereby rendering the DWS services not sustainable. To ensure that DWS services are sustainable, it is recommended that all the root causes of sustainability failure of the DWS services in Malawi should be managed in each particular WSS.

5.1.7 Combined effects of the factors that affect sustainability of DWS in Malawi

The factors that affect sustainability of DWS services in Malawi do so by triggering one or more of seven combined effects. The seven combined effects that are triggered and in turn affect sustainability of DWS services are:

a. Quantity of available raw water;
b. Quality of available raw water;
c. Capacity of infrastructure to produce and supply adequate water continually;
d. Capacity of infrastructure to produce safe water continually;
e. Continuity of infrastructure to function as required at the design stage;
f. Capacity to operate the infrastructure; and
g. Realisation of service provider expectations.

It has been established in this study that:

i. Each combined effect is as important as the other combined effects in influencing sustainability of DWS services in Malawi. This is the case because each one of them has capacity on its own to affect sustainability of DWS services.

ii. Some of the 7 combined effects are widespread in Malawi while other combined effects are not.

iii. The bigger the number of the combined effects which are in the unfavourable state for sustainability of DWS services, the more adversely affected is sustainability of DWS services in the affected WSS. This is the case where the severity of the unfavourable state of the combined effects is mild. Where the unfavourable state of the combined effects is severe, any one combined effect is enough to cause a WSS not to provide sustainable DWS services.

(section 4.2)

Based on the above findings, it is recommended that each of the 7 combined effects should be managed in each particular WSS.

5.1.8 Strategies and tactics for sustaining DWS services in Malawi

Sustainability challenges of DWS services had been encountered in some of the case WSSs for not less than 15 years by the time of this research (2014). There were different combinations of 31 reasons why DWS service sustainability challenges had not been resolved in Malawi despite being encountered for a long time (section 4.3). Employment of 7 strategies (S1 to S7) and 37 tactics (T1 to T37) discussed in section 4.3 will assist to resolve the sustainability challenges. The 7 strategies for ensuring sustainability of DWS services in Malawi are:

S1 - Ensuring that raw water for DWS is always in sufficient quantity to satisfy the demand and is at a place from where it can be supplied in a cost-effective way;

S2 - Ensuring that raw water for DWS is always of a quality that can be treated by the existing infrastructure in a cost-effective way;

S3 - Ensuring that infrastructure for DWS always has sufficient capacity to produce and supply adequate water for the demand;

S4 - Ensuring that infrastructure for DWS always has sufficient capacity to produce water which is safe for human consumption;

S5 - Ensuring that broken down infrastructure is maintained within a short time;

S6 - Ensuring that there is always sufficient capacity to operate DWS infrastructure in the required manner; and

S7 - Ensuring that there is always conducive environment for all people to use adequate quantities of potable water in order to realise health benefits and that there is adequate funds for managing the WSSs in the required manner.

For effective implementation of the strategies and tactics, 6 critical requirements (CR1 to CR6) need to be available. The 6 requirements are external support, supervision of subordinates, safety of workers, clear management arrangement of WSSs, adequate financial resources, and supportive legislation/policies. To employ the strategies and tactics in this manner, the framework developed in this study should be used. The framework outlines the process that needs to be followed. The practitioners, managers and policy makers in the DWS management in Malawi are, therefore, encouraged to use the framework in order to improve sustainability of DWS services in Malawi.

To ensure availability of the 6 critical requirements for effective implementation of the strategies and tactics, it is recommended that:

a. There should be a regulator of DWS services in Malawi;
b. Water tariffs for the financially viable WSSs should be based on the full costs incurred;
c. Government should allocate sufficient funds for DWS in the national budget;
d. Regulated external support should be provided to the WSSs;
e. At each stage of the reporting structure, there should be someone or a unit responsible for reviewing the work of the subordinates. The supervisor(s) should have qualifications and experience that will enable them to competently review the work of the subordinates; and
f. Legislation/policies should be put in place on:
    i. Regulator for DWS services;
    ii. Financing of huge-cost projects for the Water Boards;
    iii. Management of external support to the WSSs;
    iv. Health and safety of workers;
    v. Management of financially viable WSSs; and
    vi. Management of WSSs which are not financially viable.

5.1.9 The best way of using the framework developed in this research

There are a number of activities that need to be carried out in order to implement the framework that has been developed in this research for sustainability of DWS services. While some activities are already being carried out at WSSs in Malawi, there is need to collect more information, analyse and present it in the appropriate formats together with the information which is already being collected. The analysed information should be accompanied with the appropriate recommendations (refer to sections 4.5 and 4.6). It is, therefore, recommended that institutions that manage WSSs should assign a staff member or establish a unit (depending on the number of WSSs and/or their complexity) to be analysing and presenting the collected information to the authorities. Another unit to deal with the issues of DWS service sustainability should be established as part of the DWS Services Regulator or the ministry responsible for DWS. These units, both at the institutions managing the WSSs and the DWS Services Regulator (or the ministry responsible for DWS) could be known as ‘Service Sustainability Units’ and the staff ‘Service Sustainability Officers’ or similar. From the duties outlined in sections 4.5 and 4.6, it will be noted that the ‘Service Sustainability Units’ will perform duties of the current M&E and planning units in the water utilities, only that the recommendations by the ‘Service Sustainability Units’ will have to be more specific and detailed enough so that they can easily be taken forward for implementation.

5.2 ACCOMPLISHMENT OF RESEARCH OBJECTIVES AND AIM

The following paragraphs provide brief overview of how the objectives and aim of this research have been accomplished.

Objective 1: *To assess sustainability of the quantity and quality of water available to the users in the selected DWS systems in Malawi*

Interviews with service providers and water users provided insight on the adequacy and safety of the water that was provided to the users in the case WSSs. The case WSSs provided water which was either safe or unsafe, and inadequate. The consequences of this as well as the reasons why this was the case were established. These assisted in coming up with the strategies (S1 to S7), the tactics (T1 to T37) and the requirements for effective implementation of the strategies and tactics (CR1 to CR6) (sections 4.3 and 4.4).

Objective 2: *To identify the factors that affect sustainability of DWS services*

Critical review of the literature led to the identification of the factors that affect sustainability of services from various types of projects. Then the review was narrowed down to the factors that affect sustainability of DWS services which were also identified. Based on the notion that a number of factors are common to most types of projects, the factors for various types of projects and those for DWS services were combined to form a list of potential factors that could affect sustainability of DWS services in Malawi (CF1 to CF63) (chapter 2).

In the case studies, the factors that affected sustainability of DWS services in Malawi were identified. Almost all the factors identified from the literature as having potential to affect sustainability of DWS services were found to have indeed affected sustainability of DWS services in the case WSSs. The only exceptions were organisational culture, demand-responsive approach, and inter-community competitions. The respondents felt that these factors did not have influence on the sustainability of DWS services in Malawi. Apart from the factors which had already been identified in the previous studies (CF1 to CF63), additional factors were identified (AF1 to AF7). The newly identified factors assisted to explain how some factors interacted to affect sustainability of DWS services. Without these factors (newly identified), interaction of some of the factors would not be explained (section 4.3).

Objective 3: *To establish relationships that exist amongst various factors that affect sustainability of DWS services*

Literature review indicated that the only relationship that researchers had established regarding the factors that affect sustainability of DWS services was that the factors affect issues of different types. The issues that are affected are technical, managerial, policy, economic, financial, social, institutional, environmental and climatic in nature (Griffiths, 2007; Harvey and Reed, 2004; Khan, 2000) (chapter 2).

In the empirical study, root cause analyses specifically cause-and-effect analysis and construction of current reality tree were conducted. Based on the results from these analyses, new relationships of the factors were established. It was noted that there are root causes (RC1 to RC26) which kick-start interaction of the factors until combined effects (CE1 to CE7) are triggered. The triggered combined effects are the ones that directly affect sustainability of DWS services. The rest of the factors fall between the root causes and the combined effects (section 4.3).

Objective 4: *To find out the factors which need to be managed for sustainability of DWS services*

Based on the literature review, it was noted that the factors that are recommended to be managed for sustainability of DWS services appear in the literature in two ways. One is where individual factors are considered important in their own individual right, and two is where a number of factors are considered important as a collection in a framework. The individual factors that are recommended to be managed in Uganda and Malawi were studied. The factors for Uganda were studied because this is an African country with the highest sustainability level of DWS services (UNDP-WSP, 2006), and the factors for Malawi were studied because this is the country for this study. In addition, the factors that are recommended to be managed as a collection were studied for three frameworks, namely; (1) framework for sustainable rural water supply services by WaterAid (2010), (2) sustainability model of rural water supply systems by Masduqi et al, (2009), and (3) sustainability snapshot by Sugden (2003).

It was established that not all the factors that affect sustainability of DWS services are recommended to be managed. It was further noted that the factors that are recommended to be managed are not necessarily the root causes but are those which are perceived to be important because of various other reasons (section 2.6). This was the case although it is known that problems are only solved completely if it is the root causes that are addressed (Dew, 1991; Doggett, 2005). With this observation, a proposition was made that for the DWS services to be sustainable, it is the root causes that should be managed and not any other factors. This proposition was validated by the fact that in the case WSSs where the root causes were managed in the required manner, the related combined effects were in the favourable state for sustainability of the DWS services (chapter 2).

Objective 5: *To develop a framework for holistic management of factors for sustainability of DWS services in Malawi*

A framework for holistic management of the factors that affect sustainability of DWS services in Malawi has been developed. The framework provides strategies for managing all the combined effects of the factors that affect sustainability of DWS services. Further, the framework recommends employment of some tactics to manage the root causes of unfavourable state of the combined effects. In doing so, the framework manages all the factors triggered by the root causes. The framework shows the steps that need to be followed for the factors to be managed. The framework also shows the requirements which should be available if the strategies and tactics are to be implemented effectively. The developed framework is known as ‘6-step 7-strategy framework for sustainable DWS services in Malawi’ to reflect the number of steps that need to be followed, and the maximum number of strategies that need to be employed to achieve sustainable DWS services (section 4.5).

Aim: *To identify the root causes of sustainability failure of DWS services in Malawi, evaluate the outcomes of managing the root causes on sustainability of DWS services, and develop a framework for managing the identified root causes*

The aim of this research was accomplished in that all the root causes of sustainability failure of DWS services in Malawi (RC1 to RC26) were identified under objective 3. The outcomes of managing the root causes on sustainability of DWS services were evaluated under objective 1. The finding was that where the root causes were managed in the required manner, the related combined effects of the factors were in the favourable state for sustainability of DWS services. On the contrary, where the root causes were not managed in the required manner, the related combined effects were in the unfavourable state for sustainability of DWS services. The aim was further accomplished by developing a framework under objective 5 for managing the root causes. The framework, known as '6-step 7-strategy framework for sustainable DWS services in Malawi' is for facilitating sustainability of DWS services by identifying the factors which are causing and/or are likely to cause sustainability failure of DWS services (RC1 to RC26), and implementing strategies (S1 to S7) and tactics (T1 to T37) for preventing and/or reversing sustainability failure of the DWS services. The framework has been developed based on the finding that sustainability failure of DWS services in Malawi occurs when one or more combined effects are in the unfavourable state (the opposite of FS1 to FS7). This finding is based on the data collected from 10 case WSSs from Malawi studied in this research.

5.3 THEORETICAL AND PRACTICAL CONTRIBUTIONS

5.3.1 Theoretical contributions

This research has made four major theoretical contributions to the body of knowledge for DWS management. The contributions are as follows:

a. Relationships of the factors based on their interactions

There has been a need to establish the relationships of the factors which affect sustainability of DWS services based on their interactions. This need has been recognised in project management for over a decade now. Belassi and Tukel (1996) state that to achieve service sustainability, there is need to group the factors and utilise their interactions. However, this gap had not been filled ever since.

In this research, the ways in which the factors interact to affect sustainability of DWS services have been established. The new knowledge which comes from these relationships is that:

i. Twenty six (26) of the 70 factors which affect sustainability of DWS services in Malawi are the root causes of sustainability failure of DWS services (RC1 to RC26); and
ii. Seven of the 70 factors which affect sustainability of DWS services in Malawi are the combined effects (CE1 to CE7) and are the ones that directly affect sustainability of DWS services.

The rest of the factors are between the root causes and the combined effects. This supports the observation by Koo and Ariaratnam (2008) that the factors are not at the same hierarchical level; rather some factors are sub-factors. The factors between the root causes and the combined effects interact to the extent that the effect of the root causes triggers the combined effects at the top. Once triggered, the combined effects affect sustainability of the DWS services.

The combined effects will form a much simpler starting point for identifying the factors that affect sustainability of DWS services. Interactions of the identified factors will assist to identify the root causes of sustainability failure of DWS services. Knowledge of the root causes will assist to address the underlying issues, which will ensure that the sustainability challenges of DWS services will be addressed completely (Dew, 1991: Doggett, 2005).

b. Additional factors have been identified

Seven additional factors that affect sustainability of DWS services (AF1 to AF7) have been identified. The roles of these factors in the interactions that affect sustainability of DWS services have been explained. The factors will, therefore, assist in explaining how some of the factors affect sustainability of DWS services. Without identifying these factors, it was difficult to explain how some factors affect sustainability of DWS services. The consequence of not identifying all the factors was that some authors simply listed the factors in their papers without explaining how the factors affect sustainability of services (Fortune and White, 2006).

c. Generic strategies and tactics have been developed

Based on the findings of the research, generic strategies (S1 to S7) and tactics (T1 to T37) have been developed for achieving sustainability of DWS services. This is important in that those who want to improve sustainability of DWS services in their WSSs will not be required to think from scratch but review the generic strategies and tactics, and select and use the appropriate ones. As such, new strategies and tactics will only be developed where the generic strategies and tactics are not appropriate for a situation.

d. A list of critical requirements for sustainability of DWS services has been prepared

This research has clarified that some factors are neither combined effects nor root causes or the factors that fall in between. Those factors are also not the strategies or the tactics. The factors which are neither of the above are critical requirements for effective implementation of the strategies and tactics for sustainability of DWS services. It has been argued that the critical requirements are different from the strategies and tactics in that the requirements can be substituted while the strategies and tactics cannot. The critical requirements are important in that in their absence, the strategies and tactics cannot be implemented effectively. As a result, the DWS services may not be sustained. In this research, external support, supervision of subordinates, safety of workers, clear management arrangement, adequate financing, and supportive legislation/policies have been identified as the critical requirements (section 4.4).

With the new knowledge outlined in (a) to (d), there will be improved theoretical understanding of DWS management in Malawi.

5.3.2 Practical contribution

A framework for holistic management of the factors that affect sustainability of DWS services has been developed. The framework has been developed to fill a gap which was noted in practice. It was observed that the sets of factors that are recommended to be managed do not address all aspects required for sustainability of DWS services. This posed a challenge in that failure of any one aspect renders DWS services not sustainable (Abrams, 1998; Khan, 2000; Lockwood and Smits, 2011). Therefore, a new framework that will ensure that all aspects required for sustainability of DWS services will be maintained has been developed. To sustain DWS services using the new framework, the steps, strategies, tactics, and critical requirements that have been proposed in the framework should be followed and utilised respectively.

The new framework is different from the existing frameworks in that:

a. It is holistic i.e. it includes 7 strategies (S1 to S7) and 37 tactics (T1 to T37) that address all the 7 combined effects and the related root causes respectively. Generic strategies and tactics have been provided (separately) which can form a starting point in the process of developing the strategies and tactics;
b. It includes practical steps that need to be followed in the process of implementing the framework; and
c. It includes critical requirements (CR1 to CR6) necessary for effective implementation of the strategies and tactics.

It is expected that, if implemented as proposed in this research, the framework will lead to improved sustainability of DWS services in Malawi because the framework has been developed based on empirical findings.

In addition, it has been noted in the case studies that DWS services become unsustainable where the combined effects of the factors that affect sustainability of DWS services are in the unfavourable state (i.e. quantity of available raw is inadequate, quality of available raw is poor, infrastructure does not have sufficient capacity to produce and supply adequate water, infrastructure does not have sufficient capacity to produce safe water, it takes long for broken down infrastructure to be maintained, there is insufficient capacity to operate the infrastructure, and service provider expectations are not realised (the opposite of FS1 to FS7)). The ‘6-step 7-strategy framework for sustainable DWS services in Malawi’ has been designed to prevent and/or reverse sustainability failure of DWS services that occurs due to one or more combined effects being in the unfavourable state. This implies that where sustainability failure of DWS services occurs or is likely to occur due to the combined effects being in the unfavourable state (the opposite of FS1 to FS7), whether in Malawi or elsewhere, the ‘6-step 7-strategy framework for sustainable DWS services in Malawi’ should be able to prevent and/or reverse such sustainability failure. Thus, the framework developed in this research will lead to improved sustainability of DWS services not only in Malawi but also other countries where similar state of the combined effects exists.

5.4 VALIDITY OF FINDINGS

The findings of this research are valid for a number of reasons. The fact that empirical data from multiple cases led to the same findings increased the validity of the findings (Shanks and Parr, 2000).

Further, with multiple case study approach, comparative analysis was conducted through which patterns of similarities and differences across the cases were established. The comparative analysis led to valid findings because the findings were based on the similarities and differences which were observed in the case WSSs. A good example of the observed difference is that certain combined effects were in the favourable state for sustainability of DWS services in some case WSSs and not in the favourable state in the other case WSSs. Based on what was happening in the case WSSs, the reasons why certain combined effects were in the favourable state in some case WSSs and not in the favourable state in other case WSSs were established. Such findings led to the development of some strategies for ensuring sustainability of DWS services. Such strategies are valid because they are real (practical) (Pettigrew, 1990). Other recommendations were made based on what is happening in some countries in Africa like Uganda and Tanzania where sustainability of DWS services is high (UNDP-WSP, 2006). Best practices from outside Africa were used only where the contexts were similar to that of Malawi.

Furthermore, the collected data was verified and compared with data collected using other methods (Hussey and Hussey, 1997). Occurrence of various similar issues in the data collected using different methods improved the validity of the issues. An example is review of the rainfall data as a way of verifying the claim by some of the interviewees that there was a decreasing trend of rainfall in some of the case WSSs.

In addition to using different methods to collect data, different methods were also used to analyse the data. In doing this, the data and the findings were triangulated thereby improving the validity and reliability of the findings (Miles and Huberman, 1984; Easterby-Smith et al, 1991). An example is where some findings from the qualitative data were validated with the findings from the quantitative data. For instance, where more than one root causes were noted to affect a particular factor in the interaction that led to a particular combined effect, the results from principal component analyses were used to validate the root causes.

The systematicity and transparency in data analysis also improved the validity of the findings from this study. A step-by-step thematic analysis of the data as well as inclusion of the quotations of what the interviewees stated attest to this.

As regards factors, a factor was considered valid if it fitted in the current reality tree which showed how the factors interacted to affect sustainability of DWS services. Otherwise, an invalid factor would not fit.

Making sure that the number of respondents in the surveys was not less than 30, which is the recommended minimum number, and that the response rate was not less than the acceptable minimum range of 30-40%, also ensured that the results were not spurious (Moser and Kalton, 1971; Roscoe, 1975; Saunders et al, 2009; Stutely, 2003).

The validity of the research findings was also increased by requesting the participating organisations to comment on the draft thesis (Yin, 1994).

The criteria that were used to select the case WSSs also increased the validity of the findings in Malawi. This was the case in that the selected case WSSs were a representative of all types of the piped DWS systems in Malawi (Shanks and Parr, 2000).

Finally, in addition to the above, the following four qualifying criteria were satisfied for a factor to be considered valid:

1. Each factor was mentioned and supported by two or more respondents;
2. Each factor played a significant role in the sustainability (or sustainability failure) of DWS services in one or more DWS systems under one or more participating institutions;
3. Respondents provided instances of how a particular factor influenced the sustainability (or sustainability failure) of the DWS services in their respective organizations; and
4. The interview data supporting each factor was verified with data from other sources within the concerned DWS system.

5.5 CORRECTNESS OF PROPOSITION

In section 2.8, a proposition was made that *"DWS services in Malawi can be sustained if all the root causes of sustainability failure of DWS services are identified and managed".* The finding of this study is that where the root causes are managed in the manner described in section 4.3, the combined effects of the factors do not fall into the unfavourable state that would cause sustainability failure of DWS services. This means that if all the root causes were managed in the recommended manner, the combined effects would not be in the unfavourable state, hence there would be nothing to cause sustainability failure of the DWS services. As such, DWS services would be sustainable. Therefore, the proposition that *"DWS services in Malawi can be sustained if all the root causes of sustainability failure of DWS services are identified and managed"* is supported by the findings implying that it was a correct proposition.

5.6 LIMITATIONS

All studies have limitations (Simon and Goes, 2013) and this research is not an exception. Therefore, this section discusses the limitations of this research and how they were mitigated.

The first limitation of this research is that all the interviewees and respondents were from Malawi. This has been mitigated by limiting generalisation of the findings to Malawi, and only those other countries which have similar contexts as Malawi.

The second limitation relates to qualitative data analysis. Because of the nature of a doctoral study, the data were coded and themes identified by the researcher (one person). This process allowed for consistency in the method but failed to provide multiple perspectives from a variety of people with differing expertise. This limitation was mitigated by presenting in the thesis all the information on which the interpretations were based. This allows the reader to appreciate how the author drew his conclusions from the collected data.

The last limitation of this research is on how the findings have been presented in the thesis. The identities of the organisations and the respondents to which the findings relate have been concealed. This will present a challenge to the readers in that they will not be able to have a complete picture of how particular case WSSs performed on different parameters. However, the removal of the identities was necessary to protect the image of the participating organisations, and not to expose the respondents who provided sensitive information. This was important to avoid harming the participants. Murphy and Dingwall (2001) support this and advise that participants should not get harmed because of how the researcher handles the data collected from them. Otherwise, if the participating organisations and/or the respondents were to find themselves in problems because of the researcher's failure to maintain their anonymity, they would not be willing to take part in future research (Wells, 1994), among other consequences. This limitation, however, did not affect presentation of the data. The collected data was still presented only that the respondents, to which the data related, were identified by codes instead of names.

5.7 FURTHER RESEARCH

As a follow-up to this research, 6 studies are recommended:

a. Testing of the developed framework

The framework developed in this study is expected to improve sustainability of DWS services in Malawi and other countries with similar contexts because it is based on what works in practice. However, it will be important to test the framework in practice in order to identify practical limitations, if any, so that the framework can be enhanced. The author will test the framework on some of the WSSs in Malawi which are managed by some institutions which have already shown interest in the framework.

b. Similar research in other countries with similar contexts

Noting that all the interviewees and respondents in the research were from Malawi, it will be good to conduct similar research in other countries with similar contexts. This will be important for generalising the findings. The countries with similar contexts as Malawi are those where sustainability of DWS services is affected by inadequate quantity of raw water, poor quality raw water, insufficient capacity of infrastructure to produce and supply adequate water continually, insufficient capacity of infrastructure to produce safe water continually, prolonged breakdown of infrastructure, insufficient capacity to operate infrastructure, and failure to realise service provider expectations.

c. Quantifying WSSs in Malawi where quantity and quality of water supplied are satisfactory

It has been noted that comprehensive studies have not been conducted in Malawi to establish the number of WSSs that provide adequate and safe water. Considering that the estimated percentage of the people, who are served by the case WSSs but still use unsafe water, is about 60% which is high, it will be important that a comprehensive study be conducted. The results will provide information to the relevant authorities on the seriousness of the issue of sustainability failure of DWS services in Malawi.

d. Finding out why some factors are said not to be applicable in Malawi

The following 3 factors, namely; organisational culture, demand-responsive approach, and inter-community competitions are recognised in the literature as affecting sustainability of DWS services (Carter and Rwamwanja, 2006; Kerzner, 1987; Montgomery et al, 2009). However, in this research, the respondents stated that these factors did not have influence on the sustainability of DWS services in Malawi. It will be important to conduct studies to find out if these factors indeed do not apply in the WSSs in Malawi, and if so, why this is the case.

e. Establishing the minimum amount of water that would satisfy the requirements of the users in Malawi

The Government of Malawi recommends 36 litres per capita per day as the minimum quantity of water to be used in the piped DWS systems (Malawi Ministry of Irrigation and Water Development, 1994). However, most of the water users find this quantity far less than what would be adequate to satisfy their requirements. It will, therefore, be important to establish the minimum amount of water that would satisfy the requirements of the users in Malawi. This is necessary so that DWS systems can be designed appropriately.

f. Establishing the period within which drinking water supply should be restored in Malawi

The research has established that when a WSS or its part remains broken down for a certain period, the consequent disruption of drinking water supply forces people to fetch water from other sources. In most cases, the other sources provide unsafe water. This study, however, has not established the period beyond which disruption of drinking water supply forces people to fetch water from other sources. It is important that this period be established so that DWS service providers should restore DWS before expiry of the period; otherwise people are forced to use water from other sources which may not be safe for human consumption.

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APPENDICES

APPENDIX A: INSTRUMENTS USED TO COLLECT DATA

Appendix A1: Descriptive survey questionnaire

Research title: **SUSTAINABILITY MANAGEMENT OF THE RECOMMENDED QUALITY AND QUANTITY OF DRINKING WATER IN MALAWI: DEVELOPING A FRAMEWORK**

<u>DESCRIPTIVE SURVEY</u>

Introductory remarks

This research is aimed at finding ways for managing piped drinking water supply systems in Malawi to ensure sustainability of the services provided by the water supply systems. Sustainability of the drinking water supply services is necessary for the water users and service providers to maintain the benefits that they realise by drinking and using potable water, as well as rendering the services respectively.

The researcher is Asumani Ungwe who works for Northern Region Water Board and currently pursuing a PhD programme with the University of Bolton of the United Kingdom. The research is being conducted as a requirement for the University of Bolton to award a PhD.

Privacy, confidentiality and anonymity of the participants will be safeguarded in the course of conducting the research. In addition, data will be collected and reported in a way that will not explicitly divulge details of the respondents nor cause embarrassment, stress, discomfort, pain and harm to the participants.

Instructions

Please read the questions carefully. Cross the appropriate box(es) or fill in the requested information/data. There is no right or wrong answer. Please choose the answer which reflects what is happening in your organisation. Return the completed questionnaire by e-mail to anaungwe@yahoo.com or ungwe@nrwb.org.mw or through courier services to be paid for by the researcher on delivery of the mail. The physical address to which the completed questionnaire should be couriered is Asumani Ungwe, Northern Region Water Board, Kawiluwilu House, Mzuzu, Malawi.

A. DETAILS OF RESPONDENT AND HIS/HER ORGANISATION

1.	**Respondent details** Name: Title: Designation: Division/section of the organisation: E-mail address: Office phone: Mobile phone: Address:			
2.	**Organisation details** Name: Address: Sector: Number of water supply systems under the organisation:			
	Does your organisation have the following units?	Yes	No	Do not know
	Planning unit	☐	☐	☐
	Project unit	☐	☐	☐
	Operations unit	☐	☐	☐
	Maintenance unit	☐	☐	☐
	M&E unit	☐	☐	☐
	Water quality unit	☐	☐	☐

B. PROJECT FUNDING

3. How would you rate availability of funding for the piped drinking water supply projects in your organisation?

☐ Satisfactory ☐ Not satisfactory ☐ Do not know

C. ASSESSMENTS OF DRINKING WATER SUPPLY PROJECTS AND SYSTEMS

4. How often are measurements for quality and quantity of raw water for the piped drinking water supply systems in your organisation taken?

	Quality of raw water	Quantity of raw water in the source
Once every day	☐	☐
Once every week	☐	☐
Once every month	☐	☐
Once every 2 months	☐	☐
Once every 3 months	☐	☐
Once every 6 months	☐	☐
Once every year	☐	☐
Unplanned, assessments are triggered by service delivery challenges	☐	☐
Never	☐	☐
Other, specify		

5. How often does your organisation make projections of the quality of raw water that will be available in the next 5-10 years in the current water sources?

- ☐ Once every 3 months
- ☐ Once every 6 months
- ☐ Once every year
- ☐ Once every two years
- ☐ Once every five years
- ☐ 3 times during the whole life-time of a project
- ☐ 2 times during the whole life-time of a project
- ☐ Once during the whole life-time of a project
- ☐ Unplanned, the analysis is triggered by service delivery challenges
- ☐ Never

Other, specify

6. How often does your organisation undertake an analysis of whether or not the existing infrastructure will be able to treat raw water of the projected quality (in the next 5-10 years) to safe drinking water?

- ☐ Once every 3 months
- ☐ Once every 6 months
- ☐ Once every year
- ☐ Once every two years
- ☐ Once every five years
- ☐ 3 times during the whole life-time of a project
- ☐ 2 times during the whole life-time of a project
- ☐ Once during the whole life-time of a project
- ☐ Unplanned, the analysis is triggered by service delivery challenges
- ☐ Never

Other, specify

7. How often does your organisation make projections of the quantity of raw water that will be available in the next 5-10 years in the current water sources?

- ☐ Once every 3 months
- ☐ Once every 6 months
- ☐ Once every year
- ☐ Once every two years
- ☐ Once every five years
- ☐ 3 times during the whole life-time of a project
- ☐ 2 times during the whole life-time of a project
- ☐ Once during the whole life-time of a project
- ☐ Unplanned, the analysis is triggered by service delivery challenges
- ☐ Never

Other, specify

8. How often does your organisation undertake an analysis of whether or not the projected quantity of raw water in the next 5-10 years (in the current water sources) will be adequate for the demand at that time?

- ☐ Once every 3 months
- ☐ Once every 6 months
- ☐ Once every year
- ☐ Once every two years
- ☐ Once every five years
- ☐ 3 times during the whole life-time of a project
- ☐ 2 times during the whole life-time of a project
- ☐ Once during the whole life-time of a project
- ☐ Unplanned, the analysis is triggered by service delivery challenges
- ☐ Never

Other, specify

9. Who conducts the following assessments for the piped drinking water supply projects and systems in your organisation?

Assessment	Assessor of project											
	Senior management	Water quality unit	Maintenance unit	Project unit	Operations unit	Planning unit	M&E unit	Users	Government department	Consultant	Sponsor	No one
Project appraisal	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
End of construction assessment	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Analysis for checking:												
a. If existing infrastructure has capacity to treat raw water of the projected quality to safe drinking water	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
b. If the projected quantity of raw water from the current source(s) will be adequate for the demand	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

10. Which entity makes the final decision on the results from the following assessments of the piped drinking water supply projects and systems in your organisation?

Assessment	Decision maker on assessment report											
	Senior management	Water quality unit	Maintenance unit	Project unit	Operations unit	Planning unit	M&E unit	Users	Government department	Consultant	Sponsor	No one
Project appraisal	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
End of construction assessment	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Analysis for checking:												
a. If existing infrastructure has capacity to treat raw water of the projected quality to safe drinking water	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
b. If the projected quantity of raw water from the current source(s) will be adequate for the demand	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

D. REPORTING

11. Is your organisation required to submit a report on its performance to the Government?

☐ Yes ☐ No ☐ Do not know

If 'No' or 'Do not know', go to question (15)

12. At what frequency is the report in question (11) submitted to the Government?

☐ Once every three months
☐ Once every six months
☐ Once every year
☐ Never
☐ Other, specify

Other, specify

13. Does your organisation submit the report in question (11) as required?

☐ Yes ☐ No ☐ Do not know

14. What are the consequences of not submitting to the Government the report in question (11)?

- ☐ Salaries of senior managers are reduced by agreed amounts
- ☐ Contracts for senior managers may not be renewed
- ☐ Senior managers are reprimanded
- ☐ Organisation may be closed down
- ☐ Senior managers are reported to their supervisors
- ☐ No consequences

Other, specify

E. SERVICE SUSTAINABILITY

15. In your organisation, what aspects of the piped drinking water supply system should be maintained for the water supply services to be sustainable? [*Tick all those that are applicable*]

- ☐ A source that has adequate raw water
- ☐ A source that has good-quality raw water
- ☐ Infrastructure that has capacity to produce and supply adequate water
- ☐ Infrastructure that has capacity to produce safe water
- ☐ Infrastructure that functions as required all the time
- ☐ Capacity to operate the infrastructure
- ☐ Realisation of service provider expectations

Other, specify

16. On a scale of 0 to 5, where 0 is no influence and 5 is the maximum influence, to what extent did the following factors facilitate sustainability of the drinking water supply services from your organisation? [*Tick all those that are applicable*]

	0	1	2	3	4	5
A source that has adequate raw water	☐	☐	☐	☐	☐	☐
A source that has good-quality raw water	☐	☐	☐	☐	☐	☐
Infrastructure that has capacity to produce and supply adequate water	☐	☐	☐	☐	☐	☐
Infrastructure that has capacity to produce safe water	☐	☐	☐	☐	☐	☐
Infrastructure that functions as required all the time	☐	☐	☐	☐	☐	☐
Adequate capacity to operate the infrastructure	☐	☐	☐	☐	☐	☐
Realisation of service provider expectations	☐	☐	☐	☐	☐	☐

17. On a scale of 0 to 5, where 0 is no influence and 5 is the maximum influence, to what extent did the following factors impede sustainability of the drinking water supply services from your organisation? [*Tick all those that are applicable*]

	0	1	2	3	4	5
Available raw water not being adequate	☐	☐	☐	☐	☐	☐
Available raw water not being of good quality	☐	☐	☐	☐	☐	☐
Infrastructure whose production and supply capacity is less than the required quantity of water to satisfy the demand	☐	☐	☐	☐	☐	☐
Infrastructure which is not capable to produce the recommended quality of drinking water	☐	☐	☐	☐	☐	☐
It takes time to maintain infrastructure once it breaks down	☐	☐	☐	☐	☐	☐
Inadequate capacity to operate the infrastructure	☐	☐	☐	☐	☐	☐
Service provider expectations not realised	☐	☐	☐	☐	☐	☐

Other information you would want to share on this study

Thank you very much for participating in this study. We will share the results with you

Appendix A2: One-to-one interview questionnaire

Research title: **SUSTAINABILITY MANAGEMENT OF THE RECOMMENDED QUALITY AND QUANTITY OF DRINKING WATER IN MALAWI: DEVELOPING A FRAMEWORK**

ONE-TO-ONE INTERVIEWS

Introductory remarks

This research is aimed at finding ways for managing piped drinking water supply systems in Malawi to ensure sustainability of the services provided by the water supply systems. Sustainability of the drinking water supply services is necessary for the water users and service providers to maintain the benefits that they realise by drinking and using potable water, as well as rendering the services respectively.

The researcher is Asumani Ungwe who works for Northern Region Water Board and currently pursuing a PhD programme with the University of Bolton of the United Kingdom. The research is being conducted as a requirement for the University of Bolton to award a PhD.

Privacy, confidentiality and anonymity of the participants will be safeguarded in the course of conducting the research. In addition, data will be collected and reported in a way that will not explicitly divulge details of the respondents nor cause embarrassment, stress, discomfort, pain and harm to the participants.

A. DETAILS OF RESPONDENT AND HIS/HER ORGANISATION

1.	**Respondent details** Name: Title: Designation: Division/section of the organisation: E-mail address: Office phone: Mobile phone: Address:
2.	**Organisation details** Name: Address: Sector: Number of water supply systems under the organisation:

B. DETAILS OF THE WATER SUPPLY SYSTEM UNDER STUDY

3.	**Project details** Name of the system: Location of the system (district and region): Mobile phone for the person managing the system:

C. PROJECT FUNDING

4. For this water supply system, was/is funding adequate for the following activities?

Activity	Adequacy of funding	
	Adequate	Not adequate
a. Design		
b. Implementation		
c. Operation		
d. Maintenance		
e. Sustenance		

5. Why is funding for some activities adequate and for other activities not adequate?

6. How would availability of funding for this water supply system be improved?

7. What sources of funding were/are used for the following activities in this water supply system?

Funding source	Project Activity				
	Design	Implem-entation	Operation	Maintena-nce	Sustena-nce
Grants	☐	☐	☐	☐	☐
Revenue from water sales	☐	☐	☐	☐	☐
Additional equity from Government/ subvention	☐	☐	☐	☐	☐
Bonds	☐	☐	☐	☐	☐
Leasing	☐	☐	☐	☐	☐
Public-Private Sector Partnership	☐	☐	☐	☐	☐
Loans	☐	☐	☐	☐	☐
Other, specify					

D. SERVICE SUSTAINABILITY

8. Is the water produced from this water supply system
   a. adequate for the demand?
   b. safe for human consumption?

9. Why is the water produced from this water supply system
    a. not adequate for the demand?
    b. not safe for human consumption?

    [Delete either the whole question 9, (a) or (b) based on response to question 8]

10. What challenges are there in that the water produced from this water supply system is
    a. not adequate for the demand?
    b. not safe for human consumption?

    [Delete either the whole question 10, (a) or (b) based on response to question 8]

11. What is it that you do/have done, and why, for the water produced from this water supply system to be
    a. adequate for the demand?
    b. safe for human consumption?

    [Delete either the whole question 11, (a) or (b) based on response to question 8]

12. Do the following factors influence the quantity and quality of water produced from this water supply system? Explain.

Factor	The factor affects	
	Quantity	Quality
a. Quantity of available raw water		
b. Quality of available raw water		
c. Capacity of infrastructure with regard to quantity of water produced and supplied		
d. Capacity of infrastructure with regard to quality of water produced		
e. Continuity of infrastructure to function as required at design stage		
f. Capacity to operate the infrastructure		
g. Realisation of service provider expectations		

13. What makes the following factors to be *adequate/not adequate* [based on response to question 12] for this water supply system?

    a. Quantity of available raw water
    b. Quality of available raw water
    c. Capacity of infrastructure with regard to quantity of water produced and supplied
    d. Capacity of infrastructure with regard to quality of water produced
    e. Continuity of infrastructure to function as required at design stage
    f. Capacity to operate the infrastructure
    g. Realisation of service provider expectations

14. Do you have a plan of activities for ensuring
    a. Continued supply of adequate water from this water supply system? (Please provide a copy)
    b. Continued supply of safe water from this water supply system? (Please provide a copy)

15. At what stage of the project for this water supply system were measures for ensuring sustainability of the quantity and quality of water identified?

16. What sustainability frameworks/models/guidelines did you use for sustainability of services from this water supply system?

Framework	Used	Not used
Framework for sustainable rural water supply services by WaterAid (2010)		
Sustainability model of rural water supply systems by Masduqi, Soedjono, Endah and Hadi (2009)		
Sustainability snapshot by Sugden (2003)		

E. ASSESSMENTS OF DRINKING WATER SUPPLY PROJECTS AND SYSTEMS

17. What assessments did/do you undertake for this water supply system?

Assessment	Undertaken?
Project appraisal	
End of construction assessment	
Analysis for checking if existing infrastructure has capacity to treat raw water of the projected quality to safe drinking water	
Analysis for checking if there will be continued supply of adequate quantity of water	

18. For project appraisal;

    a. Why was project appraisal not done for this water supply system?

    [Question 18(a) should only be asked based on response to question 17. Go to question 19 once question 18(a) is answered]

    b. How frequently is project appraisal done?

    c. Why is it done at this frequency?

    d. What have been the results from this assessment?

    e. Who conducts this assessment?

    f. Is there any challenge in that the assessment is conducted by the entities mentioned in (e)?

    g. How are the results from this assessment used?

    h. Who makes the final decision on the recommendations made from the assessment?

    i. Who commissions the assessment to be done?

    j. What response is normally provided by the entity that makes final decision on the results from the assessment?

    k. What should be done to ensure maximum benefits from this assessment?

19. For end of construction assessment;

    a. Why was end of construction assessment not conducted for this water supply system?

    [Question 19(a) should only be asked based on response to question 17. Go to question 20 once question 19(a) is answered]

    b. What were the results from this assessment?

    c. Who conducted this assessment?

    d. Is there any challenge in that the assessment was conducted by the entities mentioned in (c)?

    e. How were the results from this assessment used?

    f. Who made the final decision on the recommendations from the assessment?

    g. Who commissioned the assessment to be done?

    h. What response was provided by the entity that made the final decision on the results from the assessment?

    i. What should be done to ensure maximum benefits from this assessment?

20. For analysis for checking if existing infrastructure has capacity to treat raw water of the projected quality to safe drinking water;

    a. Why was the analysis not done for this water supply system?

    [Question 20(a) should only be asked based on response to question 17. Go to question 21 once question 20(a) is answered]

    b. How frequently is this analysis done?

    c. Why is it done at this frequency?

    d. What have been the results from this analysis?

    e. Who conducts this analysis?

    f. Is there any challenge in that the analysis is conducted by the entities mentioned in (e)?

    g. How are the results from this analysis used?

    h. Who makes the final decision on the recommendations made from the analysis?

    i. Who commissions the analysis to be done?

    j. What response is normally provided by the entity that makes final decision on the results from the analysis?

    k. What should be done to ensure maximum benefits from this analysis?

21. For analysis for checking if there will be continued supply of adequate quantity of water;

    a. Why was the analysis not done for this water supply system?

    [Question 21(a) should only be asked based on response to question 17. Go to question 22 once question 21(a) is answered]

    b. How frequently is this analysis done?

c. Why is it done at this frequency?

d. What have been the results from this analysis?

e. Who conducts this analysis?

f. Is there any challenge in that the analysis is conducted by the entities mentioned in (e)?

g. How are the results from this analysis used?

h. Who makes the final decision on the recommendations made from the analysis?

i. Who commissions the analysis to be done?

j. What response is normally provided by the entity that makes final decision on the results from the analysis?

k. What should be done to ensure maximum benefits from this analysis?

22. How often are measurements taken of:

    a. the quantity of available raw water?
    b. the quality of available raw water?

23. How are the measurements of:

    a. the quantity of available raw water used?
    b. the quality of available raw water used?

F. REPORTING WATER QUALITY AND QUANTITY ISSUES

24. Are the following issues about this water supply system reported anywhere?

    a. Quality of water that was produced in the last few months;

    b. Quantity of water that was produced in the last few months;

    c. Quality of water to be produced in future;

    d. Quantity of water to be produced in future;

(Please provide a copy of the report)

25. How frequently are the reports in question 24 prepared?

26. Is there a unit in Government that monitors sustainability of the quality and quantity of water produced from this water supply system?

27. Would it be important to report to Government the predicted quality and quantity of water to be produced in future from this water supply system?

Appendix A3: Focus group discussion questions

Research title: **SUSTAINABILITY MANAGEMENT OF THE RECOMMENDED QUALITY AND QUANTITY OF DRINKING WATER IN MALAWI: DEVELOPING A FRAMEWORK**

FOCUS GROUP DISCUSSIONS

Introductory remarks

This research is aimed at finding ways for managing piped drinking water supply systems in Malawi to ensure sustainability of the services provided by the water supply systems. Sustainability of the drinking water supply services is necessary for the water users and service providers to maintain the benefits that they realise by drinking and using potable water, as well as rendering the services respectively.

The researcher is Asumani Ungwe who works for Northern Region Water Board and currently pursuing a PhD programme with the University of Bolton of the United Kingdom. The research is being conducted as a requirement for the University of Bolton to award a PhD.

Privacy, confidentiality and anonymity of the participants will be safeguarded in the course of conducting the research. In addition, data will be collected and reported in a way that will not explicitly divulge details of the respondents nor cause embarrassment, stress, discomfort, pain and harm to the participants.

DISCUSSION QUESTIONS

1. How much water do you use from this piped drinking water supply system?
2. Is the quantity of water that you use from this water supply system adequate?
3. Why do you use this quantity of water?
4. Do you top up water from this water supply system with water from other sources?
5. Do water supply interruptions occur at your home/premises?
6. How long does it take for water supply interruptions to end?
7. Do you store water to be used during water supply interruptions?
8. For how long is the water stored?
9. How is the water stored?

   [Ask either question 10 or 11 depending on the response to question 2]

10. What challenges do you face as a result of inadequate available water?
11. What benefits do you realise for using adequate water?
12. Is the water from this water supply system that you use safe for human consumption?

    [Ask either question 13 or 14 depending on the response to question 12]

13. What challenges do you face as a result of using water which is not safe for human consumption?
14. What benefits do you realise for using water which is safe for human consumption?

Appendix A4: Analytical survey questionnaire

Research title: **SUSTAINABILITY MANAGEMENT OF THE RECOMMENDED QUALITY AND QUANTITY OF DRINKING WATER IN MALAWI: DEVELOPING A FRAMEWORK**

ANALYTICAL SURVEY

Introductory remarks

This research is aimed at finding ways for managing piped drinking water supply systems in Malawi to ensure sustainability of the services provided by the water supply systems. Sustainability of the drinking water supply services is necessary for the water users and service providers to maintain the benefits that they realise by drinking and using potable water, as well as rendering the services respectively.

The researcher is Asumani Ungwe who works for Northern Region Water Board and currently pursuing a PhD programme with the University of Bolton of the United Kingdom. The research is being conducted as a requirement for the University of Bolton to award a PhD.

Privacy, confidentiality and anonymity of the participants will be safeguarded in the course of conducting the research. In addition, data will be collected and reported in a way that will not explicitly divulge details of the respondents nor cause embarrassment, stress, discomfort, pain and harm to the participants.

A. DETAILS OF RESPONDENT AND HIS/HER ORGANISATION

1.	Name: Organisation: Designation: Division/section of the organisation: E-mail address:

B. REASONS FOR SOME SITUATIONS IN DRINKING WATER SUPPLY SYSTEMS IN MALAWI

2. The statements below indicate causes of certain situations that occur in the piped drinking water supply systems. On a scale of 0 to 5, where 0 is disagree, 1 is agree and 5 is strongly agree, indicate *[by ticking appropriate box]* the extent to which you agree with each statement. Your rating should be based on what is happening in piped drinking water supply systems under your organisation. Where you are considering more than one system, the rating should be based on the extreme case.

	0	1	2	3	4	5	Not sure
Unavailability of spare parts results in delayed maintenance of leaking water supply facilities. Consequently, a lot of water is lost hence available raw water is not adequate for drinking water supply during some part of a year	☐	☐	☐	☐	☐	☐	☐
Unavailability of appropriate maintenance tools results in delayed maintenance of leaking water supply facilities. Consequently, a lot of water is lost hence available raw water is not adequate for drinking water supply during some part of a year	☐	☐	☐	☐	☐	☐	☐
Human resources management issues such as number of staff members deployed to undertake maintenance works results in delayed maintenance of leaking water supply facilities. Consequently, a lot of water is lost hence available raw water is not adequate for drinking water supply during some part of a year	☐	☐	☐	☐	☐	☐	☐
Unavailability of spare parts results in delayed maintenance of leaking water supply facilities. Consequently, a lot of water is lost rendering the capacity of the infrastructure to produce and supply adequate water insufficient	☐	☐	☐	☐	☐	☐	☐
Unavailability of appropriate maintenance tools results in delayed maintenance of leaking water supply facilities. Consequently, a lot of water is lost rendering the capacity of the infrastructure to produce and supply adequate water insufficient	☐	☐	☐	☐	☐	☐	☐
Human resources management issues such as number of staff members deployed to undertake maintenance works results in delayed maintenance of leaking water supply facilities. Consequently, a lot of water is lost rendering the capacity of the infrastructure to produce and supply adequate water insufficient	☐	☐	☐	☐	☐	☐	☐
Unavailability of spare parts results in delayed maintenance of leaking water supply facilities. Consequently, a lot of water is lost hence the quantity of water produced is not adequate to satisfy the demand. In order to satisfy the demand, raw water is rushed through the treatment plant with the consequence that the water that is produced is not safe for human consumption	☐	☐	☐	☐	☐	☐	☐
Unavailability of appropriate maintenance tools results in delayed maintenance of leaking water supply facilities. Consequently, a lot of water is lost hence the quantity of water produced is not adequate to satisfy the demand. In order to satisfy the demand, raw water is rushed through the treatment plant with the consequence that the water that is produced is not safe for human consumption	☐	☐	☐	☐	☐	☐	☐

	0	1	2	3	4	5	Not sure
Human resources management issues such as number of staff members deployed to undertake maintenance works results in delayed maintenance of leaking water supply facilities. Consequently, a lot of water is lost hence the quantity of water produced is not adequate to satisfy the demand. In order to satisfy the demand, raw water is rushed through the treatment plant with the consequence that the water that is produced is not safe for human consumption	☐	☐	☐	☐	☐	☐	☐
Capacity of infrastructure to produce adequate water is not sufficient because there is increased demand for water due to: (1) population increase	☐	☐	☐	☐	☐	☐	☐
(2) increase in non-domestic activities that use water	☐	☐	☐	☐	☐	☐	☐
Capacity of infrastructure to produce safe water is not sufficient because increased demand for water forces plant operators to push more raw water (per unit time) through the treatment plant than specified. The increased water demand which leads to this is due to: (1) population increase	☐	☐	☐	☐	☐	☐	☐
(2) increase in non-domestic activities that use water	☐	☐	☐	☐	☐	☐	☐
Drinking water supply service provider expectations are not realised (1) because the infrastructure does not produce and supply adequate water	☐	☐	☐	☐	☐	☐	☐
(2) because of poor economic status of the water users	☐	☐	☐	☐	☐	☐	☐

Other information you would want to share on this study

Thank you very much for participating in this study. We will share the results with you

APPENDIX B: PUBLISHED JOURNAL PAPER

COMBINED EFFECTS OF THE FACTORS THAT AFFECT SUSTAINABILITY OF DRINKING WATER SUPPLY SERVICES IN MALAWI: A VALIDATED PERSPECTIVE

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ABSTRACT

The factors that affect sustainability of drinking water supply services (i.e. quality and quantity of drinking water) do so by triggering some combined effects which in turn affect sustainability of the drinking water supply services. This study was conducted to identify such combined effects. The combined effects were identified by conducting a cause-and-effect analysis in a focus group discussion, and validated through a descriptive survey and multiple case studies conducted in Malawi. The respondents of the survey were 40 drinking water supply practitioners while the multiple case studies involved ten drinking water supply systems. The finding is that the factors trigger seven combined effects. The paper argues that all the seven combined effects should be managed if all the aspects required for sustainability of drinking water supply services are to be maintained; and the drinking water supply services sustained.

Keywords: drinking water supply, service sustainability factors, interaction of factors, combined effects of factors, categorisation of factors, Malawi

INTRODUCTION

The concept of sustainable development requires that all human needs should be available to both the present and future generations (United Nations World Commission on Environment and Development, 1987). A drinking water supply (DWS) service, which is one of the human needs, accomplishes its main purpose of maintaining and/or improving public health when the drinking water is of a certain quality and quantity (Bostoen, 2005; UNICEF and WHO, 2012). However, in Malawi, these parameters (quality and quantity of drinking water) deteriorate with time, which is in sharp contrast with sustainable development. For example, some rural piped DWS systems that used to supply safe water to all the users, no longer do so (World Bank, 2011). For instance, the results from the water quality surveillance conducted in 2009 in 10 rural DWS systems show that, on average, 86% of the samples collected from different places in the 10 areas were of contaminated water (Malawi Ministry of Irrigation and Water Development, 2009). As regards the situation in the individual DWS systems, it was noted that all the samples (100%) from 8 of the 10 DWS systems were of contaminated water, while 80% and 64% of the samples from the ninth and tenth DWS systems respectively were of contaminated water. The 10 DWS systems are located in different parts of Malawi.

In terms of the quantity of water supplied, information from 167 piped DWS systems in Malawi (19 piped DWS systems out of a total of 186 systems in 2014 were not studied because they were only about 2 years old) shows that the quantity of water available for supply to the users in 85% of the systems was less than the Government of Malawi recommended quantity of 36 litres per person per day. Consequently, water supply to the users was either intermittent or the flows from the taps were so low that it took a long time to fill a container. Low water flows from the taps occurred mostly in the rural areas.

For the urban areas, the challenge was mainly water supply intermittency. The average number of hours per day that water was available to the users in the urban areas was less than the planned 24 hours (World Bank, 2011). The results from a consumer survey conducted by the Ministry of Water Development and Irrigation in 2013 in 8 areas show that, on average, water was available to the users for 13 hours per day (Malawi Ministry of Water Development and Irrigation, 2013). In some areas, water was available only for 6 hours per day.

The challenge with the above situations was that people were forced to complement the inadequate safe water with the available contaminated water (Harvey and Reed, 2006). The result was that people contracted water-borne diseases despite having access to some safe water (Malawi Ministry of Health, 2011). There was, therefore, a need to ensure that the quality and quantity of drinking water were sustained. This study was part of a larger research aimed at finding ways for ensuring sustainability of the quality and quantity of drinking water in Malawi. In this study, sustainability of DWS services (quality and quantity of drinking water) is continued flow of water at the same rate and quality as per the design of the supply system.

FACTORS THAT AFFECT SUSTAINABILITY OF DWS SERVICES

The authors of this paper conducted an extensive review of the literature to identify the factors that affect sustainability of the quality and quantity of drinking water. Forty three (43) studies, conducted from 1960s to date

(2014), were reviewed. The review was done following holistic and life cycle approaches, and as such, all possible factors that can affect service sustainability at any stage of a project were noted. The review resulted in the identification of 76 factors that affect or can potentially affect sustainability of DWS services. The identified factors are in Appendix A. Appendix A shows that a number of studies have been conducted to identify the factors that affect sustainability of DWS services. When the factors from different studies are put together, the list is long and almost exhaustive.

RECOMMENDED FACTORS FOR SUSTAINABILITY OF DWS SERVICES

The researchers and practitioners recommend that, when managing sustainability of the quality and quantity of drinking water, concentration should be on some of the factors. The factors on which concentration is recommended are referred to by different names such as main factors (Binder, 2008), key factors (McConville and Mihelcic, 2007), and critical factors (Sugden, 2003). The number of these factors varies. For example, Binder (2008) identified 3 factors while WaterAid (2010) identified 13 factors. The researchers and practitioners consider the main, key or critical factors important because:

a. The factors are listed in the best-practice guidelines (McConville and Mihelcic, 2007);
b. The factors are cited frequently in the literature (Lockwood, 2003; WaterAid, 2010);
c. The factors are given more weight than other factors by the authors (Lockwood, 2003);
d. The factors are observed to affect sustainability of water supply facilities (Masduqi, Soedjono, Endah and Hadi, 2009);
e. Personal experience of the authors and practitioners suggests that the factors are important (McConville and Mihelcic, 2007; WaterAid, 2010); and
f. The factors are identified and given more weight than other factors by the respondents.

The situation in Malawi was not different. Only financial self-sufficiency and decentralised day-to-day management of the DWS systems were considered as the factors that needed to be managed for sustainability of DWS services (World Bank, 2007).

The result of concentrating on a few factors was that the other factors were not managed. Consequently, DWS services were unsustainable not only in Malawi but also other countries (Khan, 2000; Saucer, Reilly and Shenhar, 2009). Examples of such other countries included Mauritania, Madagascar, Niger, DR Congo, Rwanda and Mozambique, among others (UNDP-WSP, 2006).

Gbadegesin and Olorunfemi (2007) state that for DWS services to be sustainable, there is need to adopt a holistic approach whereby all the factors should be considered rather than focussing on a few factors. Abrams (1998), Khan (2000) and Lockwood and Smits (2011) explain that it is important that all the factors should be managed otherwise management of some factors and not other factors, results in certain aspects required for sustainability of DWS services not being maintained; and that failure of any one aspect renders DWS services unsustainable. This, however, does not necessarily mean each and every factor should be managed in isolation. The factors could be grouped so that it is the interactions of the grouped factors that should be managed (King, 1996). After all, it is the combined effects of the factors that matter to achieve service sustainability, and not individual factors (King, 1996).

COMBINED EFFECTS OF THE FACTORS NOT IDENTIFIED

With the recommendation that it is the combined effects of the factors that should be managed for sustainability of DWS services, and that this recommendation had been made about two decades earlier, one expected the combined effects to have been identified and documented in the literature. However, literature review showed that the combined effects of the factors had not yet been identified. As such, the factors were not managed to address the combined effects but for the reasons mentioned in the preceding section. Consequently, only some of the factors were managed. Failure to manage all the factors resulted in certain aspects required for sustainability of DWS services not being maintained, which led to unsustainable DWS services (Abrams, 1998; Khan, 2000; Lockwood and Smits, 2011).

This study was, therefore, conducted to identify the combined effects of the sustainability factors for DWS services in Malawi.

RESEARCH METHODOLOGY

Having noted the above problem, one of the researchers in the current study facilitated a focus group discussion in Malawi in which a cause-and-effect analysis of the factors was conducted. The objective of the analysis was to identify the combined effects of the factors that affect sustainability of DWS services. Five participants took part in the analysis. The five participants were people who worked at Northern Region Water Board and had between 5 and 15 years experience in DWS management. The cause-and-effect analysis was done based on the experience of the participants and the descriptions in the literature.

After identifying the combined effects in the focus group discussion, a descriptive survey was conducted to assess if the combined effects identified from the cause-and-effect analysis affected sustainability of the DWS services in Malawi. In addition, the survey was conducted to establish the extent to which the combined effects facilitated and impeded sustainability of DWS services in Malawi. Three questions, which were part of a larger questionnaire, were dedicated to the present research. One question required the respondents to identify from a given list of the combined effects, the combined effects that were important for sustainability of DWS services in their water supply systems. The other two questions sought perceptions of the respondents on the extent that each of the combined effects facilitated or impeded sustainability of the DWS services in Malawi.

The respondents in the descriptive survey were people who worked in the organisations that provided DWS services in Malawi. The total number of the possible respondents in the survey was 50. Since this number is small, it was decided that data would be collected from all the possible respondents and that all the data would be analysed. A questionnaire was e-mailed to all the 50 possible respondents, and 40 completed questionnaires were returned. This represents 80% response rate, which is much higher than the acceptable minimum range of 30-40% for surveys (Moser and Kalton, 1971).

The participants in the focus group discussion as well as the respondents in the descriptive survey were people who worked at middle management level, and were involved in project design, implementation, operation, maintenance, and undertook monitoring and evaluation of the DWS systems, which are key activities that affect sustainability of DWS services (Gosling, 2010; Griffiths, 2007; Khan, 2000). People at middle management level were considered to be appropriate respondents for the focus group discussion and descriptive survey because they were the ones who either undertook the above activities in person or supervised implementation of the activities directly. As such, these people had adequate knowledge of the management of the DWS services in Malawi.

Multiple case studies were also conducted in the research. There were two objectives for the case studies. One, to identify the factors that affected sustainability of the quality and quantity of drinking water in Malawi, and two, to establish how those factors affected the sustainability of the two parameters i.e. quality and quantity of drinking water. Ten piped DWS systems in Malawi were studied. Purposive sampling was used to select the cases that were studied based on the criteria that ensured that the selected DWS systems were representative of all the piped DWS systems in Malawi. The criteria that were used related to the types of water sources, types of the institutions that managed the water supply systems, means of supplying water, and the administrative regions where the water supply systems were located, among others. The names of the selected case DWS systems are in table 1 and their locations in Malawi are shown in figure 1.

Interviews, document analysis, and observation were used to collect data from the case DWS systems. The interviewees were the senior managers from the institutions that managed the case DWS systems. In order to get a comprehensive and varied account of the key issues in the case DWS systems, at least three senior managers were interviewed from each of the five institutions that managed the case DWS systems. A total of 17 respondents were interviewed. The five institutions that managed the case DWS systems were the Department of Water Supply Services, Blantyre Water Board, Central Region Water Board, Northern Region Water Board and Southern Region Water Board. Considering their positions, educational qualifications, work experience, and professional background, the senior managers were considered to have adequate knowledge of DWS management in their organisations (Saqib, Farooqui and Lodi, 2008).

Table 33: Overview of the case DWS systems for the current research

Case No.	Name of piped DWS system	Administrative region in Malawi	Period of operation (years)	Type of managing institution	Type of water source	Sustainability of		Means of water supply
						Minimum required quantity of water supplied per capita	Quality of water supplied	
1	Chintheche	North	29	Water Board	Lake	√	√	Pumping
2	Chipoka rural	Central	23	Community	River	X	X	Gravity
3	Chipoka town	Central	29	Water Board	Lake	√	√	Pumping
4	Chiradzulu	South	49	Water Board	River	√	√	Gravity
5	Chitipa	North	46	Water Board	Boreholes	√	√	Pumping
6	Ighembe	North	40	Community	River	X	X	Gravity
7	Mudi	South	61	Water Board	Dam	√	√	Pumping
8	Mzuzu	North	74	Water Board	Dam	√	√	Pumping
9	Nkhamanga-Lunyina	North	36	Community	River	X	X	Gravity
10	Salima	Central	39	Water Board	Boreholes	√	√	Pumping

Key: √ ~ sustained X ~ not sustained

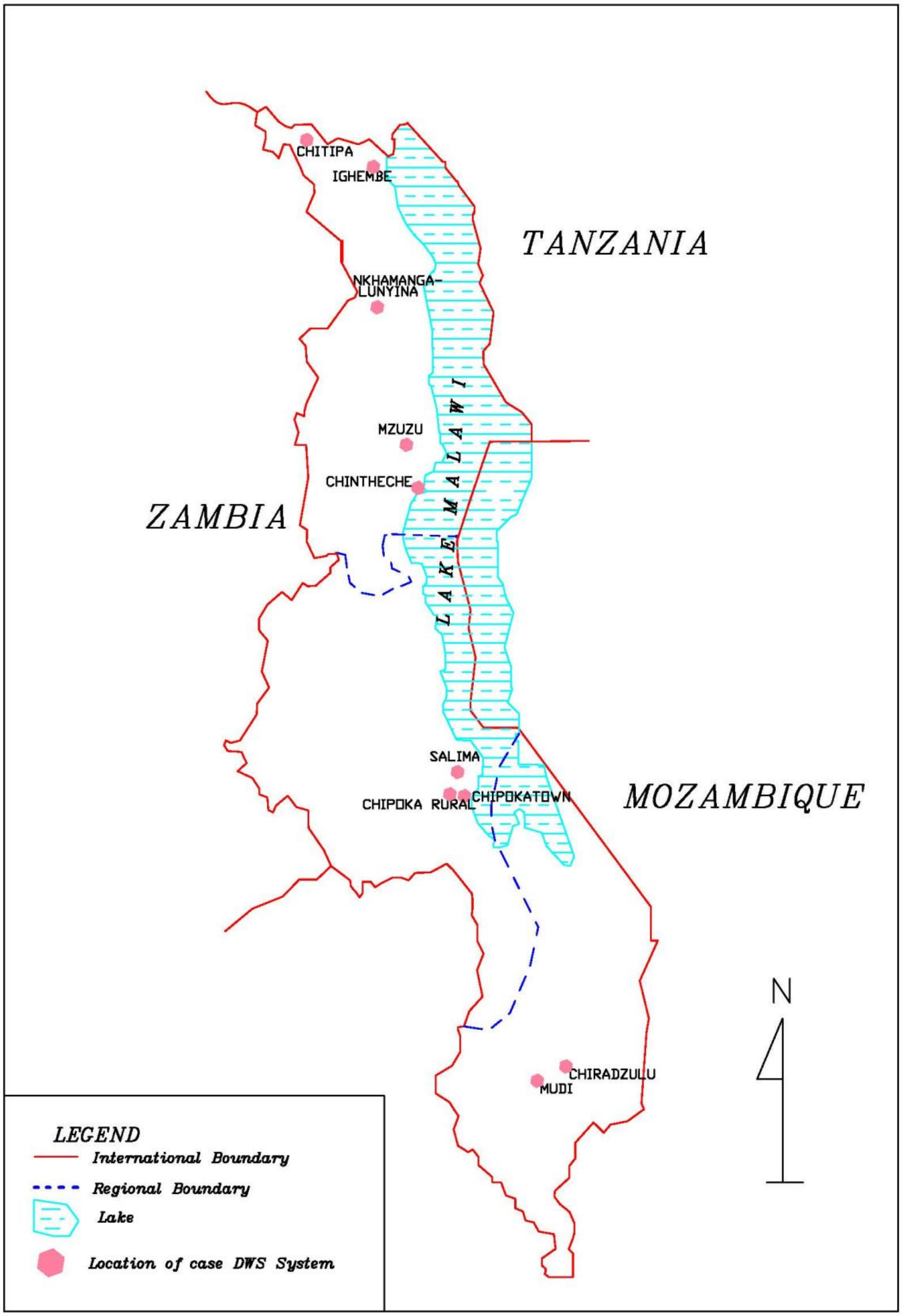

Figure 1: Map of Malawi showing locations of the case DWS systems

RESULTS, ANALYSIS AND DISCUSSION

Results from the multiple case studies revealed that different combinations of the factors in Appendix A affected sustainability of DWS services in the particular case DWS systems. Overall, 61 of the 64 factors (the number of the factors in Appendix A drops to 64 from 76 when the factors that refer to one main factor are combined) affected sustainability of the quality and quantity of drinking water in Malawi. This shows that the majority of the factors identified from the literature, as having potential to affect sustainability of the quality and quantity of drinking water, were applicable in practice in Malawi. The three factors which were not applicable in practice in the case DWS systems are organisational culture, demand-responsive approach, and inter-community competitions. The respondents felt that these factors did not have influence on the sustainability of DWS services in Malawi.

The factors that were applicable in Malawi were then subjected to a cause-and-effect analysis in a focus group discussion. The results of the analysis show that the interactions of the factors led to seven combined effects which in turn affected sustainability of DWS services. The seven combined effects are:

1. Quantity of available raw water;
2. Quality of available raw water;
3. Capacity of infrastructure to produce and supply adequate water continually;
4. Capacity of infrastructure to produce safe water continually;
5. Continuity of infrastructure to function as required at the design stage;
6. Capacity to operate the infrastructure; and
7. Realisation of service provider expectations.

The above findings from the cause-and-effect analysis are supported by the results from the case studies which showed that all the factors that contributed to the sustainability failure of the DWS services in the ten case DWS systems led to either:

a. Inadequate raw water;
b. Poor quality raw water;
c. Insufficient capacity of infrastructure to produce and supply adequate water;
d. Insufficient capacity of infrastructure to produce safe water;
e. Prolonged breakdown of infrastructure;
f. Insufficient capacity to operate the infrastructure; or
g. Failure to realise service provider expectations.

The seven combined effects and the factors under them are presented in table 2. Table 2 has been prepared based on a fish-bone diagram (which cannot fit on a page like this one because the factors are many) for unsustainable DWS services which has been drawn based on the results of the cause-and-effect analysis carried out in this study.

In the descriptive survey, the respondents were asked “What aspects of your piped DWS systems should be maintained for the DWS services to be sustainable?” A list of the seven combined effects was provided. The

Table 34 : Categorisation of the factors that affect sustainability of DWS services based on the combined effects

Factors \ Combined effect	1: Quantity of available raw water							
Level 1	Perennial source of water			Efficiency of using water resources				Equity in distribution of water resources
Level 2	Climate change impacts	Capacity of water catchment area		Water demand management	Level of water loss			Extent of abiding with water rights provisions
Level 3		Natural condition of water catchment area	Social/economic activities in water catchment area		Timeliness of maintaining leaking water supply infrastructure			Enforcement of water rights provisions
Level 4			Protection of water catchment area		Availability of spare parts	Availability of maintenance tools	Human resource management	

Factors \ Combined effect	2: Quality of available raw water		
Level 1	Natural condition of water catchment area	Social/economic activities in water catchment area	Climate change impacts
Level 2		Protection of water catchment area	
Level 3			
Level 4			

Factors \ Combined effect	3: Capacity of infrastructure to produce and supply adequate water continually						
Level 1	Growth of water demand		Quality of raw water		Level of water loss		
Level 2	Population increase	Increase in non-domestic activities that use water	Natural condition of water catchment area	Social/economic activities in water catchment area	Timeliness of maintaining leaking water supply infrastructure		
Level 3				Protection of water catchment area	Availability of spare parts	Availability of maintenance tools	Human resource management
Level 4							

Factors \ Combined effect	4: Capacity of infrastructure to produce safe water continually						
Level 1	Growth of water demand		Quality of raw water		Level of water loss		
Level 2	Population increase	Increase in non-domestic activities that use water	Natural condition of water catchment area	Social/economic activities in water catchment area	Timeliness of maintaining leaking water supply infrastructure		
Level 3				Protection of water catchment area	Availability of spare parts	Availability of maintenance tools	Human resource management
Level 4							

Factors \ Combined effect	5: Continuity of infrastructure to function as required at design stage												
Level 1	Capacity to carry out proper maintenance of infrastructure								Climate change impacts	Type of technology			Quality of infrastructure
Level 2	Preventative maintenance	Troubleshooting	Rate of breakdown	Extent of breakdown		Availability of spare parts	Availability of maintenance tools	Involvement of motivated personnel		Performance of designers	Project owner requirements	Project sponsor requirements	Performance of contractor
Level 3	Availability of spare parts	Involvement of trained personnel	Vandalism of infrastructure	Age of infrastructure	Vandalism of infrastructure			Level of remuneration			Project owner´s flexibility to change its predetermined requirements based on expert advice	Project sponsor's knowledge of local situation versus dictation of requirements	
Level 4		Continued training of staff	Supply of water to people living close to the infrastructure		Supply of water to people living close to the infrastructure								

Factors \ Combined effect	6: Capacity to operate the infrastructure					
Level 1	Human resource management	Involvement of trained personnel	Involvement of motivated personnel	Adequacy/availability of supplies e.g. power supply		
Level 2		Continued training of staff	Level of remuneration	Type of technology		Performance of suppliers
Level 3				Performance of designers	Project sponsor requirements	
Level 4					Project sponsor's knowledge of local situation versus dictation of requirements	

Factors \ Combined effect	7: Realisation of service provider expectations					
Level 1	Realistic objectives	Continued use of supplied water as expected at design stage				
Level 2	Integrity in project appraisal	User satisfaction with service	Realisation of benefits by users			Availability of alternative water sources
Level 3	Political interference on where a project should be implemented	User involvement in decision-making	Quantity of potable water used		Quality of water used	Political will on the need for people to use safe water
Level 4		Amount of information shared with the users	Capacity of infrastructure to produce adequate water	Economic status of users	Capacity of infrastructure to produce safe water	

Source: Cause and effect analysis conducted under this study based on works of the authors shown in Appendix A respondents were supposed to tick the combined effects that were important for sustainability of DWS services in their piped DWS systems. It is noted that the respondents ticked different combinations of the seven combined effects as the aspects that needed to be maintained for sustainability of DWS services in their water supply systems in Malawi. Overall, each of the seven combined effects was ticked. This further validates the finding from the cause-and-effect analysis that there are seven combined effects that directly affect sustainability of DWS services. The percentages of the respondents who ticked each combined effect are shown in table 3.

Table 35: % of respondents who identified the seven combined effects as important

Combined effect	Percentage of respondents
Adequacy of raw water	98
Quality of raw water	85
Continuity of infrastructure to functions as required	85
Capacity of infrastructure to produce and supply adequate water	83
Capacity of infrastructure to produce safe water	78
Capacity to operate infrastructure	78
Realisation of service provider expectations	60

Table 3 indicates that some combined effects affected sustainability of DWS services in almost all the piped DWS systems where the respondents worked, while other combined effects affected sustainability of DWS services in only some of the piped DWS systems where the respondents worked. To check whether or not the differences in the proportions of the piped DWS systems affected by each of the seven combined effects (based on the percentages of the respondents who identified the combined effects as important) were statistically significant, a one-sample t-test statistical analysis was conducted. The results of the analysis show that the differences were statistically significant. This implies that some of the seven combined effects were widespread in Malawi while other combined effects were not. This is supported by the results from the multiple case studies which show that, out of the ten case DWS systems:

a. Quantity of available raw water affected sustainability of DWS services in 4 case DWS systems;
b. Quality of available raw water affected sustainability of DWS services in 4 case DWS systems;
c. Capacity of infrastructure to produce and supply adequate water continually affected sustainability of DWS services in 4 case DWS systems;
d. Capacity of infrastructure to produce safe water continually affected sustainability of DWS services in 3 case DWS systems;
e. Continuity of infrastructure to function as required at the design stage affected sustainability of DWS services in 3 case DWS systems;
f. Capacity to operate the infrastructure affected sustainability of DWS services in 5 case DWS systems; and
g. Realisation of service provider expectations affected sustainability of DWS services in 1 case DWS system.

Overall, each of the seven combined effects affected at least one case DWS system.

The respondents were also requested to rate the extent of influence of each of the seven combined effects on sustainability of DWS services in Malawi. The rating was done on a scale of 0 to 5, where 0 is no influence and 5 is maximum influence. For each combined effect, total scores were calculated against each score point (i.e. 0, 1, 2, 3, 4 and 5), and the results are presented in tables 4 and 5.

Table 36: Total scores on how the seven combined effects facilitate DWS service sustainability in Malawi

Combined effect	Total scores against each score point					
	0	1	2	3	4	5
Adequacy of raw water	0	1	0	0	28	150
Quality of raw water	0	1	2	21	32	110
Continuity of infrastructure to functions as required	0	1	6	3	52	100
Capacity of infrastructure to produce and supply adequate water	0	0	0	9	60	95
Capacity of infrastructure to produce safe water	0	0	2	18	44	105
Capacity to operate infrastructure	0	0	12	21	20	90
Realisation of service provider expectations	0	1	10	30	32	75

Table 37: Total scores on how the seven combined effects impede DWS service sustainability in Malawi

Combined effect	Total scores against each score point					
	0	1	2	3	4	5
Adequacy of raw water	0	0	2	9	12	130
Quality of raw water	0	4	0	21	40	60
Continuity of infrastructure to functions as required	0	2	6	15	20	95
Capacity of infrastructure to produce and supply adequate water	0	3	2	6	28	75
Capacity of infrastructure to produce safe water	0	0	6	21	32	75
Capacity to operate infrastructure	0	5	8	9	16	60
Realisation of service provider expectations	0	3	8	30	20	45

Using the total scores in tables 4 and 5, two one-way analyses of variance (ANOVA) were conducted, one where the combined effects were considered to be facilitating sustainability of DWS services in Malawi, and the other where the combined effects were considered to be impeding sustainability of DWS services in Malawi. The results show that the level of influence of the seven combined effects on sustainability of DWS services in Malawi was not statistically different. This means that statistically the combined effects had the same level of influence on the sustainability of DWS services in Malawi. This finding implies that there were no trivial combined effects amongst the seven combined effects. Each combined effect was as important as the other combined effects in influencing sustainability of DWS services in Malawi. It was noted in the case studies that, depending on the severity of the unfavourable state of the combined effects, each combined effect has capacity on its own to affect sustainability of the quality and/or quantity of drinking water. For example, supply of water completely stopped for some time in some of the case DWS systems due to either unavailability of raw water, or poor quality raw water or unavailability of water purification chemicals, among others.

The benefit of having identified the seven combined effects is that these will form a much simpler starting point for identifying the root causes of DWS service sustainability failure, as opposed to when the 76 factors identified from the literature are scattered all over. For example, where one is not sure as to what is causing failure of the sustainability of DWS services, a question needs to be asked whether or not all the seven combined effects in table 2 are responsible for the failure. Based on expert knowledge, and/or knowledge that people have about a water supply system, and/or by observing a water supply system, the combined effects that are responsible for the failure can be identified. Then the factors that contribute to the unfavourable state of the identified combined effects (e.g. inadequate quantity of available raw water) can be identified (factors in the lower rows of table 2 can be a starting point), and should be placed under each of the identified combined effects. By analysing the interactions of the factors under each combined effect, the root causes can be identified.

Conversely, the proposed categorisation of the factors based on the seven combined effects can assist to confirm or exonerate a factor suspected to be the root cause of undesirable state of the combined effects. For example, a speculation that high population increase is the root cause of sustainability failure of DWS services can be systematically investigated using table 2. It will be noted from combined effect 3 in table 2 that population increase affects the growth of water demand which has an impact on the capacity of the infrastructure to produce and supply adequate water continually. Working downwards through combined effect 3 in table 2, questions like; is it high population increase that leads to inadequacy of water, or fast developmental improvements, or failure to develop additional water supply system in time, or delays in upgrading the infrastructure, may be asked. By analysing the interactions of these factors, high population increase could either be exonerated or confirmed as a root cause of the insufficient capacity of infrastructure to produce and supply adequate water continually in a particular situation.

Table 2 was used to identify root causes for the undesirable state of the seven combined effects that affect sustainability of DWS services in Malawi. This was done in a larger research of which this is a part.

Once the root causes are identified, corrective measures will be taken on them. By taking corrective measures on the root causes as opposed to managing the factors which are not the root causes, the problem of drinking water supply service sustainability failure will be solved completely (Doggett, 2005).

Lastly, it should be mentioned that apart from the factors under the seven combined effects in table 2, the participants who conducted the cause-and-effect analysis under this study, also noted other important factors. The other factors are six in number and are:

a. External support;
b. Supervision of subordinates;
c. Safety of workers;

d. Clear management arrangement;
e. Adequate financing; and
f. Supportive legislation/policies.

The above factors are neither combined effects nor root causes or the factors that fall in between. These factors are also not the strategies or the tactics. These are factors that are required for effective implementation of the strategies and tactics for sustainability of the quality and quantity of drinking water in Malawi. Further discussion of these factors is beyond the scope of this paper.

CONCLUSIONS AND RECOMMENDATIONS

There are seven combined effects of the factors that affect sustainability of DWS services in Malawi. The seven combined effects are quantity of available raw water, quality of available raw water, capacity of infrastructure to produce and supply adequate water continually, capacity of infrastructure to produce safe water continually, continuity of infrastructure to function as required at the design stage, capacity to operate the infrastructure, and realisation of service provider expectations.

Some of the seven combined effects are widespread in Malawi while others are not. On the other hand, the level of influence of the combined effects on the sustainability of DWS services in Malawi is the same. Each of the seven combined effects is as important as the other combined effects. It is, therefore, recommended that the Government of Malawi should develop a policy that will require that the criteria to be used in the appraisal and monitoring and evaluation of DWS projects should take into account all the seven combined effects. This will ensure that DWS services are sustainable, as all the aspects required for sustainability of DWS services will be maintained. Sustainable DWS services will show that sustainable development is achieved in DWS. This will be different from the current situation whereby the factors that are recommended to be managed for sustainability of the DWS services in Malawi (i.e. financial self-sufficiency and decentralised day-to-day management of the DWS systems) do not directly address any of the seven combined effects. This has a consequence that the DWS services are not sustainable. The DWS services need to be sustainable because sustainable development in most of the other sectors cannot be achieved without sustainable DWS services (Kataoka, 2002; Mwanza, 2003).

The seven combined effects are also the names of the categories of the sustainability factors for DWS services proposed in this study (table 2). This categorisation ensures that all the factors that affect a particular combined effect fall under one category. This is important for analysing interactions of the factors so that root causes of the unfavourable state of the combined effects (e.g. inadequate quantity of available raw water) can be identified.

It should be noted, however, that since this study was conducted in Malawi only, the findings cannot be generalised to other countries. However, the findings could be considered as a guide to conduct similar studies in other countries.

There is also a need to conduct studies to find out why the respondents in this study stated that organisational culture, demand-responsive approach, and inter-community competitions did not have influence on the sustainability of DWS services in Malawi. Such studies will be important considering that previous studies noted that these factors affected sustainability of DWS services in other countries.

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Appendix A: Factors that affect or can potentially affect sustainability of drinking water supply services drawn from works of various authors

No.	Sustainability factors	Authors																																										
		Avots, 1969	Kerzner, 1987	Morris and Hough, 1987	Pinto and Slevin, 1988	Roark et al, 1989	UNCHS-Habitat, 1989	Sanvido et al, 1992	Hodgkin, 1994	Clarke,1995	Abrams, 1998	Sara and Katz, 1998	ADB-ADF, 1998	Lopes and Flavell, 1998	WSP, 1998	Carter et al, 1999	Fowler and Walsh, 1999	WSSCC, 2000	Aini et al, 2001	Parry-Jones et al, 2001	Sonuga, et al, 2002	Mwanza, 2003	Harvey and Reed, 2003	Lockwood, 2003	Mukherjee and van Wijk, 2003	Sugden, 2003	Harvey and Reed, 2004	WHO and UNICEF, 2004	Abdullah and Ramly, 2006	Butler and Memon, 2006	Carter and Rwamwanja, 2006	UNDP-WSP, 2006	Aini et al, 2007	Bhandari and Grant, 2007	Morita-Lou and Waters, 2008	Montgomery et al, 2009	Rietveld et al, 2009	Hunter et al, 2010	WaterAid, 2010	Yigitcanlar and Dur, 2010	Harvey, 2011	Man et al, 2011	Al-Tmeemy et al, 2011	Mimrose et al, 2011
1	Quality of project designs i.e. specifications from designs								√							√									√									√							√			
2	Type of technology e.g. water supply system that the benefiting community can sustain					√			√														√			√	√								√	√					√			
3	Quality of infrastructure								√			√				√									√																			
4	Proper handover of new infrastructure																																	√										
5	Spare parts supply																									√	√					√			√									
6	Infrastructure that works as required						√																																					
7	Continuous upgrading of infrastructure												√																															
8	Preventative maintenance						√																																					
9	Rate and extent of breakdown of infrastructure					√										√																												
10	Performance by consultants																									√									√	√								
11	Performance by contractors																									√									√	√								
12	Capacity to maintain infrastructure					√			√						√	√				√					√	√	√								√	√					√			
13	Capacity to operate infrastructure					√			√						√	√				√					√	√	√								√	√					√			

No.	Sustainability factors	Authors																																										
		Avots, 1969	Kerzner, 1987	Morris and Hough, 1987	Pinto and Slevin, 1988	Roark et al, 1989	UNCHS-Habitat, 1989	Sanvido et al, 1992	Hodgkin, 1994	Clarke,1995	Abrams, 1998	Sara and Katz, 1998	ADB-ADF, 1998	Lopes and Flavell, 1998	WSP, 1998	Carter et al, 1999	Fowler and Walsh, 1999	WSSCC, 2000	Aini et al, 2001	Parry-Jones et al, 2001	Sonuga, et al, 2002	Mwanza, 2003	Harvey and Reed, 2003	Lockwood, 2003	Mukherjee and van Wijk, 2003	Sugden, 2003	Harvey and Reed, 2004	WHO and UNICEF, 2004	Abdullah and Ramly, 2006	Butler and Memon, 2006	Carter and Rwamwanja, 2006	UNDP-WSP, 2006	Aini et al, 2007	Bhandari and Grant, 2007	Morita-Lou and Waters, 2008	Montgomery et al, 2009	Rietveld et al, 2009	Hunter et al, 2010	WaterAid, 2010	Yigitcanlar and Dur, 2010	Harvey, 2011	Man et al, 2011	Al-Tmeemy et al, 2011	Mimrose et al, 2011
14	Performance by suppliers																									√									√	√								
15	Use of alternative water sources																													√														
16	Efficiency of using water resources																																		√									
17	Rewards for good operation																																	√										
18	Rewards for good maintenance																																	√										
19	Involvement of trained personnel					√			√			√	√											√	√							√			√									
20	Involvement of motivated personnel					√			√			√	√											√	√							√			√									
21	Organisational structure adaptation to a project		√																																									
22	Organisational culture adaptation to a project		√																																									
23	Human resources management																												√															
24	Realistic objectives									√																																		
25	Stability of operating environment e.g. economic status																						√			√	√																	
26	Population growth rate																											√																
27	Developmental improvements																											√																
28	Equity in distribution of water resources																	√																										
29	Environmental considerations													√																														
30	Protection of water source															√																			√									
31	Perennial source of water							√																																				

No.	Sustainability factors	Authors																																										
		Avots, 1969	Kerzner, 1987	Morris and Hough, 1987	Pinto and Slevin, 1988	Roark et al, 1989	UNCHS-Habitat, 1989	Sanvido et al, 1992	Hodgkin, 1994	Clarke,1995	Abrams, 1998	Sara and Katz, 1998	ADB-ADF, 1998	Lopes and Flavell, 1998	WSP, 1998	Carter et al, 1999	Fowler and Walsh, 1999	WSSCC, 2000	Aini et al, 2001	Parry-Jones et al, 2001	Sonuga, et al, 2002	Mwanza, 2003	Harvey and Reed, 2003	Lockwood, 2003	Mukherjee and van Wijk, 2003	Sugden, 2003	Harvey and Reed, 2004	WHO and UNICEF, 2004	Abdullah and Ramly, 2006	Butler and Memon, 2006	Carter and Rwamwanja, 2006	UNDP-WSP, 2006	Aini et al, 2007	Bhandari and Grant, 2007	Morita-Lou and Waters, 2008	Montgomery et al, 2009	Rietveld et al, 2009	Hunter et al, 2010	WaterAid, 2010	Yigitcanlar and Dur, 2010	Harvey, 2011	Man et al, 2011	Al-Tmeemy et al, 2011	Mimrose et al, 2011
32	Quantity of raw water																																						√					
33	Quality of raw water																																						√					
34	Stakeholder participation								√																√										√									
35	Gender and poverty focus					√																			√										√									
36	Social considerations													√																														
37	User involvement																√																											
38	Demand-responsive approach											√													√											√								
39	User satisfaction with a service					√			√							√									√																			
40	Equity in distribution of water supply services																																		√									
41	Achievement of benefits by users e.g. health and economic benefits					√																																						
42	Community participation																			√																								
43	Full cost recovery tariffs												√																															
44	Collection of all generated revenue												√																															
45	Operation cost																																		√									
46	Maintenance cost																																		√									
47	Institutional set-up								√																																√			
48	Management type of water supply system e.g. decentralised management, autonomous entity								√			√											√			√	√							√	√						√			

No.	Sustainability factors	Authors																																										
		Avots, 1969	Kerzner, 1987	Morris and Hough, 1987	Pinto and Slevin, 1988	Roark et al, 1989	UNCHS-Habitat, 1989	Sanvido et al, 1992	Hodgkin, 1994	Clarke,1995	Abrams, 1998	Sara and Katz, 1998	ADB-ADF, 1998	Lopes and Flavell, 1998	WSP, 1998	Carter et al, 1999	Fowler and Walsh, 1999	WSSCC, 2000	Aini et al, 2001	Parry-Jones et al, 2001	Sonuga, et al, 2002	Mwanza, 2003	Harvey and Reed, 2003	Lockwood, 2003	Mukherjee and van Wijk, 2003	Sugden, 2003	Harvey and Reed, 2004	WHO and UNICEF, 2004	Abdullah and Ramly, 2006	Butler and Memon, 2006	Carter and Rwamwanja, 2006	UNDP-WSP, 2006	Aini et al, 2007	Bhandari and Grant, 2007	Morita-Lou and Waters, 2008	Montgomery et al, 2009	Rietveld et al, 2009	Hunter et al, 2010	WaterAid, 2010	Yigitcanlar and Dur, 2010	Harvey, 2011	Man et al, 2011	Al-Tmeemy et al, 2011	Mimrose et al, 2011
49	Assessment and addressing of risks			√																																								
50	Lessons from past projects/organisational learning																											√																
51	Involvement of senior managers				√																																							
52	Troubleshooting				√																																							
53	Continual evaluation and improvement								√																		√									√								
54	Post-project implementation external support								√							√												√				√			√	√								
55	Project owner requirements	√																																										
56	Project sponsor regulations								√														√																					
57	Health and safety measures							√																																				
58	Supervision by superiors e.g. district authorities, government ministry																																	√										
59	Water loss that is within acceptable levels												√																															
60	Water demand management																													√														
61	Climate change impacts																																							√				
62	Continued use of supplied water											√																																
63	Growth of water demand																																									√		
64	Age of infrastructure																																									√		

No.	Sustainability factors	Authors																																										
		Avots, 1969	Kerzner, 1987	Morris and Hough, 1987	Pinto and Slevin, 1988	Roark et al, 1989	UNCHS-Habitat, 1989	Sanvido et al, 1992	Hodgkin, 1994	Clarke,1995	Abrams, 1998	Sara and Katz, 1998	ADB-ADF, 1998	Lopes and Flavell, 1998	WSP, 1998	Carter et al, 1999	Fowler and Walsh, 1999	WSSCC, 2000	Aini et al, 2001	Parry-Jones et al, 2001	Sonuga, et al, 2002	Mwanza, 2003	Harvey and Reed, 2003	Lockwood, 2003	Mukherjee and van Wijk, 2003	Sugden, 2003	Harvey and Reed, 2004	WHO and UNICEF, 2004	Abdullah and Ramly, 2006	Butler and Memon, 2006	Carter and Rwamwanja, 2006	UNDP-WSP, 2006	Aini et al, 2007	Bhandari and Grant, 2007	Morita-Lou and Waters, 2008	Montgomery et al, 2009	Rietveld et al, 2009	Hunter et al, 2010	WaterAid, 2010	Yigitcanlar and Dur, 2010	Harvey, 2011	Man et al, 2011	Al-Tmeemy et al, 2011	Mimrose et al, 2011
65	Continued training																							√																				
66	Incentives for stakeholders															√																												
67	Political support/ interference																							√																				
68	Geographic focus																														√													
69	Supply of maintenance tools											√																																
70	Institutional set-up								√																																			
71	Availability/adequacy of supplies e.g. power supply																																				√							
72	Appropriateness of policies																																					√						
73	Wasteful usage of water																		√																									
74	Leaking water supply facilities																																√											
75	Activities taking place in water catchment area																																											√
76	Realisation of service provider expectations																																										√	

Source: Compiled by the authors of this paper

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